FISHERY DATA SERIES NO. 54

STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE TANANA RIVER DRAINAGE[1]

By

Robert A. Clark
and
William P. Ridder

Alaska Department of Fish and Game
Division of Sport Fish
Juneau, Alaska 99802

March 1988
Reprinted June 1990

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-3, Job No. G-8-1.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

ABSTRACT

Arctic grayling *Thymallus arcticus* were captured by electrofishing, seining, and weir trapping in seven river systems and two lake systems of the Tanana drainage of interior Alaska in 1987. Stock assessment of Arctic grayling in these systems was accomplished through estimation of population abundance, age composition, and size composition. In three river systems and one lake system, population abundance was estimated by mark-recapture experiments. Population size in the Chena River was 31,502 Arctic grayling greater than 149 millimeter fork length; 16,097 Arctic grayling greater than 199 millimeter fork length in Fielding Lake; 2,775 Arctic grayling greater than 249 millimeter fork length in the Richardson Clearwater River; and, 10,520 Arctic grayling greater than 289 millimeter fork length in Shaw Creek. Population size in two 4.8-kilometer sections of the lower Goodpaster River ranged from 639 to 901 Arctic grayling greater than 149 millimeter fork length. Relative abundance of Arctic grayling (electrofishing catch per day) was estimated in the Delta Clearwater and Richardson Clearwater Rivers. Catch per unit effort estimates in two 4.8-kilometer sections of the Delta Clearwater River ranged from 3.0 to 6.7 Arctic grayling caught per day, while catch per unit effort in three sections of the Richardson Clearwater River ranged from 24.0 to 58.5 Arctic grayling per day. Age and size composition estimates were obtained from all nine systems. Age 4 and age 7 Arctic grayling were strongly represented in most of these systems, indicating similar patterns of recruitment throughout the Tanana drainage. In contrast, size at age estimates indicate that growth rate is highly variable between systems throughout the Tanana drainage.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, population size, catch rate, age composition, size composition, relative stock density, tag loss, electrofishing, bootstrapping, length selectivity, Tanana River Drainage.

INTRODUCTION

It is generally agreed that Arctic grayling *Thymallus arcticus*, hereafter referred to as grayling, are the most valuable sport fishery resource of interior Alaska. Grayling consistently rank second or third in total Alaska freshwater sport harvest by species. Interior waters provide about 60% of this harvest, making the Interior, and particularly the Tanana River drainage, the largest grayling fishery in North America. With increasing human population, tourism, and improving access to fishing, angling pressure on Tanana drainage stocks is increasing approximately 5% annually. The popularity of the grayling is exemplified by the fact that it is consistently rated as the number one sport species by interior Alaskan fishermen. Holmes (1981) found that over 90% of Fairbanks fishermen fish for grayling each year. In 1985, Holmes (1987) found that over 85% of Tanana drainage fishermen fish for grayling each year.

The Tanana drainage grayling resource consists of a set of stocks that utilize runoff rivers, spring-fed creeks, bog-fed creeks, and lake systems for spawning, feeding, overwintering, and rearing. Use of these systems by grayling stocks ranges from a simple single river life history strategy (e.g., Chena River; see Tack 1980) to complex migration patterns (e.g., the Shaw Creek/Richardson Clearwater River/Tanana River migration pattern; see Ridder 1985). Because of the wide range of life history strategies exhibited by grayling stocks in the Tanana drainage, the status and geographic description of many grayling stocks in the drainage are incomplete.

This study was conducted on the naturally occurring grayling populations in the Tanana drainage with the major emphasis directed toward the stocks that support the largest fisheries. These major stocks are found in: the Chena, Salcha, Chatanika, Goodpaster, Delta Clearwater, and Richardson Clearwater Rivers, Shaw Creek, and Fielding and Tangle Lakes (Figure 1). Past studies of Tanana drainage grayling provide a good general knowledge of grayling life history (Roguski and Winslow 1969, Roguski and Tack 1970, Tack 1971-1976, Hallberg 1977-1982, Holmes 1983-1985, Peckham and Ridder 1979, and Ridder 1980-1985). More recent studies have focused on the effects of environmental variables on grayling recruitment and their importance in determining the harvestable surplus of riverine grayling stocks. In addition, recent attempts to model the dynamic interactions of the primary rate functions (recruitment, growth, and mortality) of riverine grayling stocks are yielding important insights into the effect of sport fishing on grayling stocks of the Tanana drainage.

In 1985, Holmes et al. (1986) found that significant declines in grayling abundance, catch rates of the fisheries, and harvest in these fisheries had occurred in recent years. Results of a dynamic pool model of the Chena River grayling stock and fishery indicated that severe recruitment overfishing was occurring in the Chena River, and that environmental conditions during the grayling's first year of life can significantly affect subsequent recruitment to the harvestable stock (Holmes et al. 1986). Based on these results and input from anglers, regulations were promulgated in spring 1987 to restrict harvest of grayling in the Chena River, Delta Clearwater River, Richardson Clearwater River, and Shaw Creek. During the fall of 1987, the Alaska Board

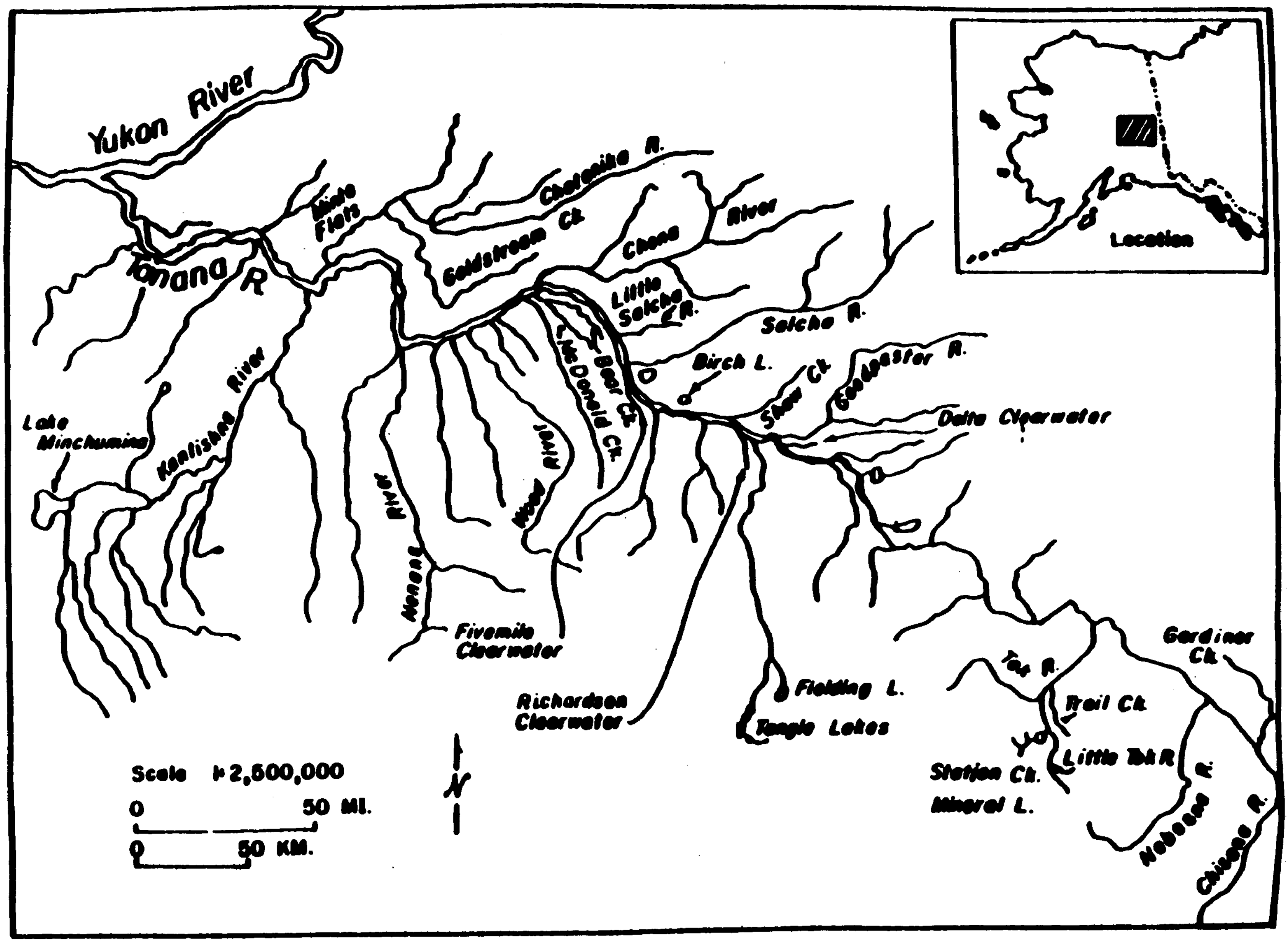

Figure 1. Tanana drainage research areas.

of Fisheries adopted regulations to restrict harvest of grayling in the Salcha River and Mineral Lake outlet in addition to the above mentioned waters. The newly implemented regulations are:

1) restrict the harvest of grayling to fish 305 mm (12 in) or greater in total length;

2) restrict the methods of harvest to unbaited artificial lures only; and,

3) eliminate the harvest of grayling during the spawning period.

The long-term goals of this research project are:

1) to increase basic knowledge of grayling life history strategies, such as spawning behavior, migration patterns, and habitat preferences;

2) to develop standard methods to assess grayling stocks in rivers and lakes of the Tanana drainage;

3) to collect population data from the major grayling stocks of the drainage, such that accurate and precise estimates of abundance, growth, mortality, and recruitment can be calculated; and,

4) to use the aforementioned population statistics in models that accurately describe the interactions of these statistics in the real world and that predict the probable consequences of management actions already implemented or contemplated.

The objectives of the 1987 research efforts were:

1) to estimate the absolute abundance of age 3 and older grayling in the Chena and Richardson Clearwater Rivers, Shaw Creek, and Fielding Lake;

2) to estimate the absolute abundance of age 3 and older grayling for each of two 4.8-km long sections of the Goodpaster River;

3) to estimate electrofishing catch rate (CPUE) of age 3 and older grayling in each of two 4.8-km long sections of the Delta Clearwater River as a measure of relative abundance;

4) to estimate electrofishing CPUE of age 3 and older grayling in the lower 12.8 km of the Richardson Clearwater River as a measure of relative abundance;

5) to estimate the mean fork length (FL) at age of grayling in the Chena, Salcha, Chatanika, Tangle, Goodpaster, Delta Clearwater, and Richardson Clearwater Rivers, Caribou Creek, and Fielding and Tangle Lakes; and,

6) to estimate the age composition of grayling in the Chena, Salcha, Chatanika, Tangle, Goodpaster, Delta Clearwater, and Richardson Clearwater Rivers, Caribou Creek, and Fielding and Tangle Lakes.

METHODS

The methods portion of this document is divided into three specific sections. The first section addresses the estimation of absolute abundance of grayling, either in a whole system (Fielding Lake, Richardson Clearwater River, and Shaw Creek) or a specific area of a system (Chena River and Goodpaster River). The second section addresses the estimation of relative abundance of grayling in the Delta Clearwater and Richardson Clearwater Rivers. The last section addresses the estimation of mean length at age and age class composition in grayling stocks of the Tanana drainage.

Estimation of Absolute Abundance

Absolute abundance of age 3 and older grayling was estimated in the Chena River, Richardson Clearwater River, Goodpaster River, Shaw Creek, and Fielding Lake. All estimates of absolute abundance were conducted as capture/recapture experiments. These experiments ranged from modified Petersen (Chapman 1951) methods to complex Jolly-Seber (Seber 1982) methods. When a multiple-sample design was used to estimate absolute abundance and the capture histories of individual fish were known, program CAPTURE (White et al. 1982) was used:

1) to objectively determine if there were significant departures of the data from the assumptions necessary to multiple-sample experiments; and,

2) to then objectively select the appropriate estimator.

If the capture histories of individual fish were not known, the modified Schnabel formula of Chapman (1952) was used to estimate absolute abundance. Since the ages of individual grayling are not known at the time of marking, all grayling greater than 149 mm FL were assumed to be age 3 or greater. After aging of scale samples, the actual ages are recorded and used to apportion abundance estimates into the actual age classes.

Grayling sampled during abundance estimation were measured for fork length (FL; tip of snout to fork of tail) to the nearest 1 mm. Lengths were taken, not only to provide length at age data, but to estimate and correct for bias due to length selectivity of the capture gear. Except for the Richardson Clearwater estimation experiment, all grayling greater than 149 mm FL (199 mm FL for lakes and Shaw Creek) were tagged with individually numbered Floy internal anchor tags and the adipose or ventral fin was removed. Data collected from tagged fish were used to estimate mean growth increments from capture to recapture (over one or more seasons), to document capture histories of individual fish during estimation of absolute abundance, and to provide estimates of recruitment and mortality during one or more seasons. The adipose or ventral fin was removed as a second "mark", allowing for estimation of tag loss rate and accurate recording of marked fish.

Chena River Study Design:

The absolute abundance of grayling age 3 and older was estimated by dividing the lower 152 river kilometers into two sections and performing capture/recapture population estimates in each section. All capture/recapture estimates were performed with a pulsed-DC (direct current) electrofishing system mounted on a 6.1 m river boat. The first section, hereafter called the Lower Chena, encompassed the lower 72 km of the Chena River (from the mouth to the Chena Dam; Figure 2). The second section, hereafter called the Upper Chena, encompassed the upper 80 km of the Chena River (from the Chena Dam to river kilometer 152). The Lower Chena section was further stratified into two subsections, Lower Chena "A" and Lower Chena "B". The lower 40 km of the Lower Chena was subsection "A" and the upper 32 km of the Lower Chena was subsection "B".

Based on data collected from eight 3.2-km sections in 1986, the absolute abundance of grayling in the Lower Chena was estimated by performing multiple-sample population estimates in each of four randomly selected 3.2-km sample areas. Two of the sample areas were selected from each of the two Lower Chena subsections ("A" and "B"). The four sample area abundance estimates were then expanded to estimate the total abundance of grayling in the Lower Chena. Two 3.2-km sample areas were electrofished once every day for 5 days (both areas in the same Lower Chena subsection). Electrofishing was performed along both banks of each sample area. Abundance estimation in all four 3.2-km sample areas was completed between 29 June and 10 July.

Absolute abundance of grayling in the Upper Chena River was estimated by performing a modified Petersen estimate for the entire 80 km section. Clark and Ridder (1987b) found that relative precision of modified Schnabel abundance estimates was low in four 3.2-km sample areas of the Upper Chena. They surmised that avoidance behavior and movement of grayling out of the sample area significantly reduced precision in the Upper Chena. The entire 80 km section was sampled by two electrofishing boats once a week for 2 weeks. One sample event took four out of the possible 5 days in a week. The entire experiment was conducted between 20 and 23 July for the first sample and 27 and 30 July for the second (recapture) sample.

Richardson Clearwater River Study Design:

The absolute abundance of age 3 and older grayling was estimated in the lower 12.8 km of the 19.2-km long Richardson Clearwater River with a multiple-sample design using a boat-mounted AC electrofishing system for the first 4 days and a DC unit for the last 2 days of sampling. The upper 6.4 km of river was not included in the abundance estimate because of its narrow width and low fish density. Previous sampling, Peckham (1978) and Peckham and Ridder (1979), found that few grayling utilized the upper 6.4 km of the Richardson Clearwater River. The lower 12.8 km of river was divided into three physically distinct sections (Figure 3). These sections were electrofished once a day with intervals of at least 1 day between events. Section 2 (the "middle" section) is separated from the other two sections by large pools (270 and 810 m long) formed by old beaver dams. Section 1 extends 4.8 km upstream from the mouth

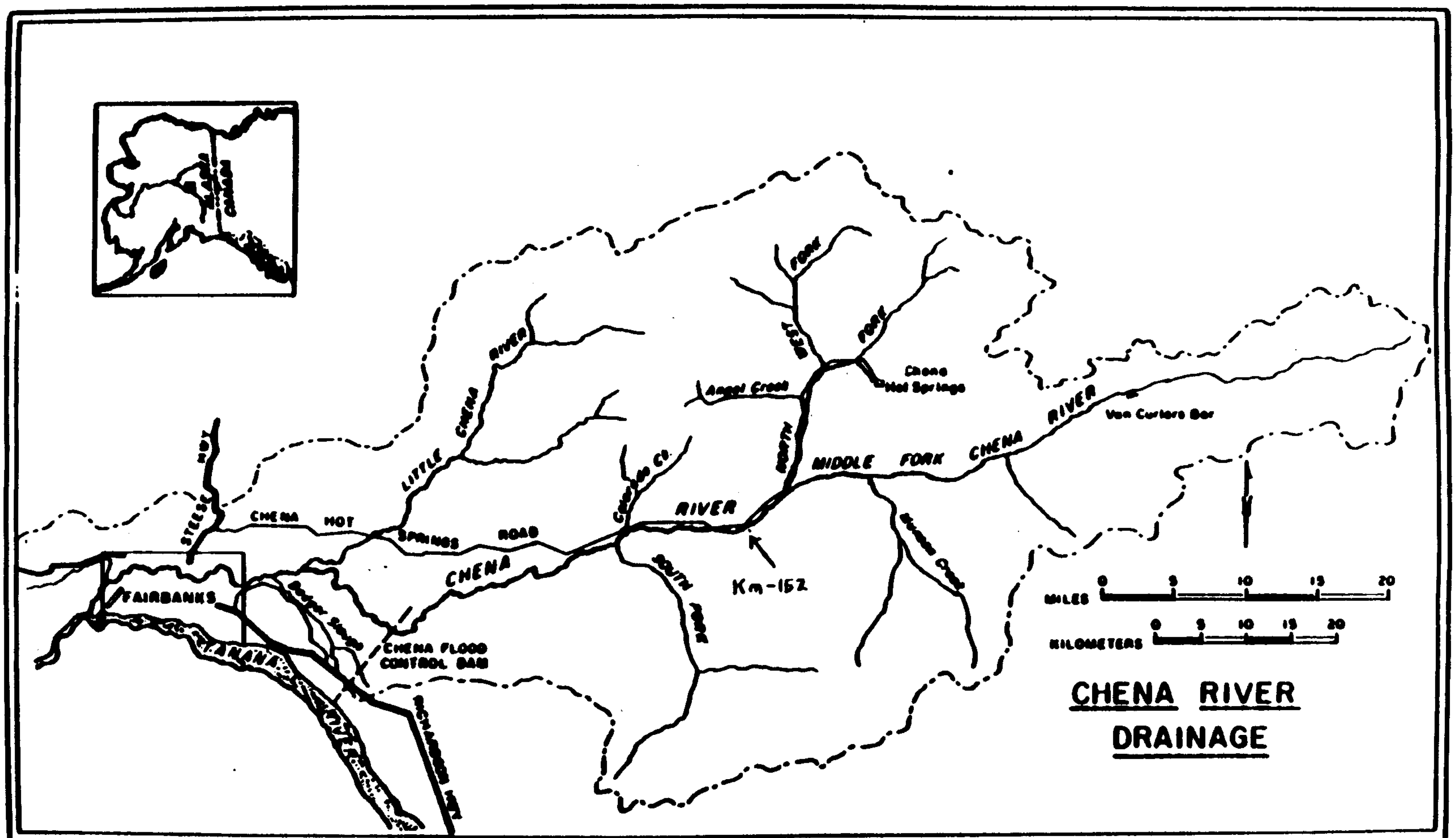

Figure 2. The Chena River drainage.

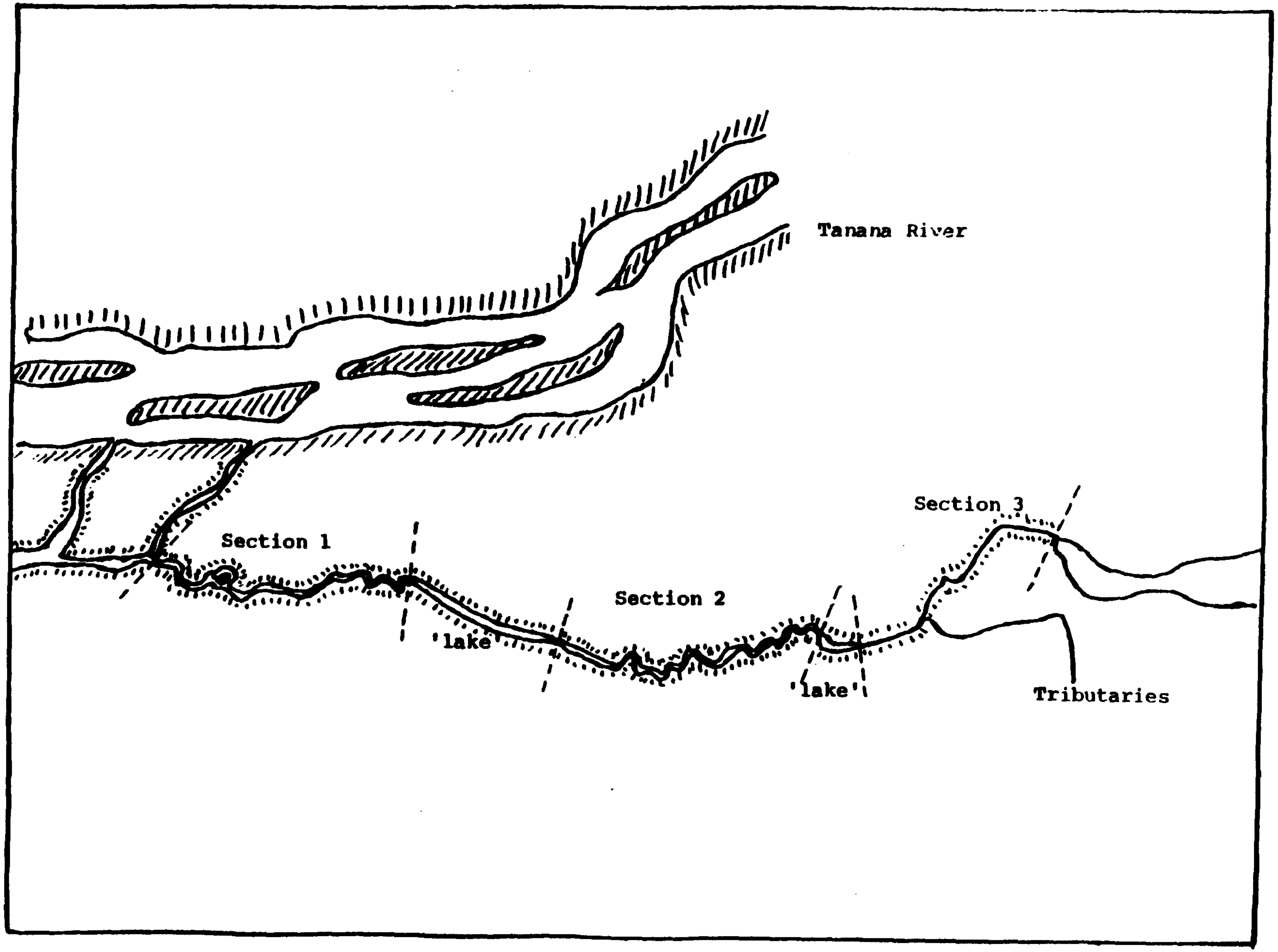

Figure 3. Study sections at the Richardson Clearwater River.

to the longest "pool". Section 2 extends the same distance upstream from the head of this "pool" to the second "pool". Section 3 is 3.2 km long and extends upstream to a second tributary stream (see Ridder 1983 for a detailed description of the electrofishing sections). Sampling was conducted from 7 to 17 July and on 3 August.

Captured grayling were sampled after completing electrofishing of a section. All grayling were marked by removing a small portion of the upper lobe of the caudal fin. To facilitate mixing of marked and unmarked fish, marked grayling were released individually throughout the same section in which they were captured.

Goodpaster River Study Design:

The absolute abundance of age 3 and older grayling was estimated in each of two 4.8-km sections of the Goodpaster River. Two electrofishing boats, one AC and one pulsed-DC, were used to perform multiple-sample abundance estimates in each of these sections. Past studies, Ridder (1980 - 1985), Holmes et al. (1986), and Clark and Ridder (1987b), have used the average of abundance estimates from the two sections as an index of total grayling abundance in the lower Goodpaster River. The same two river sections have been sampled every year since 1973. The downstream section extends from river kilometer 4.8 through river kilometer 9.6. The upstream section extends from river kilometer 24 through river kilometer 28.8. To facilitate marking and releasing of fish, each 4.8-km section was electrofished in 1.6-km stretches. After both sides (one electrofishing boat along each bank) of the 1.6-km stretch were sampled, all fish were measured for length, marked (150 to 199 mm FL were finclipped; ≥ 200 mm FL were tagged), and released throughout the stretch. Each of the 4.8-km sections was electrofished once each day for a maximum of 6 days. Sampling of the two sections was conducted between 4 and 10 August.

Shaw Creek Study Design:

Since 1981, the absolute abundance of age 4 (greater than 199 mm FL) and older grayling has been estimated using the generalized Jolly-Seber model (see Clark and Ridder 1987b; Seber 1982). Grayling were tagged during the previous year (1986) at a weir constructed on Caribou Creek, a major spawning system of Shaw Creek (Figure 1). During the following spring (1987), grayling were sampled with a pulsed-DC electrofishing system at the mouth of Shaw Creek (in the Tanana River) just prior to breakup at Shaw Creek. In the past, recaptures were obtained from the spring grayling fishery at Shaw Creek (see Ridder 1985). Since the fishery was closed in 1987, recovery of tags was conducted with a pulsed-DC electrofishing system at the mouth of Shaw Creek during the time the fishery would have been harvesting fish. This estimate of grayling abundance was germane to the time of tagging in 1986.

Additionally, a modified Petersen estimate of grayling abundance in 1987 was conducted. All grayling captured during electrofishing were either tagged, if unmarked, or the tag number and color noted from a previous capture. The recapture run was made at the weir on Caribou Creek, noting all fish "marked" at Shaw Creek that spring and all fish captured (either unmarked, or tagged previously but not sampled earlier at the mouth of Shaw Creek). Chapman's

(1951) modification of the Petersen estimator was used to estimate the abundance of grayling in Shaw Creek in 1987. Marking of fish at the mouth of Shaw Creek was conducted between 15 and 23 April. Recaptures were recovered at the Caribou Creek weir between 3 and 11 June. This estimate was germane to the time of tagging in 1987.

Fielding Lake Study Design:

The absolute abundance of age 3 and older grayling was estimated with Chapman's (1951) modification of the Petersen estimator. The abundance estimate was accomplished in two phases. The first phase consisted of capture events performed with two pulsed-DC electrofishing boats and two fyke traps. Sampling occurred right after ice breakup in the lake (15 to 21 June). The electrofishing boats were fished once each night, concentrating fishing effort in the areas adjacent to lake inlet streams. The two fyke traps (10 mm meshes) were placed at the mouths of Two Bit Creek and Caribou Bay Creek, two inlet streams known to have concentrations of spawning grayling (Figure 4). These traps essentially blocked passage of grayling from the inlet streams to the lake. All fish greater than 199 mm FL were sampled for age (scale sample), tagged with Floy tags, and released at or near the capture site. Additionally, the outlet of Fielding Lake was sampled with a 15 m beach seine (15 m x 2 m, with 10 mm mesh). All fish of sufficient length were sampled as above and released in the outlet stream.

The second phase consisted of capture runs performed with two pulsed-DC electrofishing boats and a 15 m beach seine. From 20 to 25 August, Fielding Lake was sampled in the same manner as in phase one, except that no fyke nets were used in the inlet streams. All fish captured were examined for marks and released. In 1986, Clark and Ridder (1987b) found significant recruitment (growth) of grayling less than 200 mm FL into the markable population between marking and subsequent recapture runs. A non-parametric procedure developed by Robson and Flick (1965) was used to detect and adjust for recruitment bias in the 1987 abundance estimate.

Data Analysis:

The assumptions necessary for accurate estimation of absolute abundance in a closed population are as follows (Seber 1982):

1) the population is closed (no change in the number of grayling in the population during the estimation experiment);

2) all grayling have the same probability of capture in the first sample or in the second sample, or marked and unmarked grayling mix randomly between the first and second samples;

3) marking of grayling does not affect their probability of capture in the second sample;

4) grayling do not lose their mark between sampling events; and,

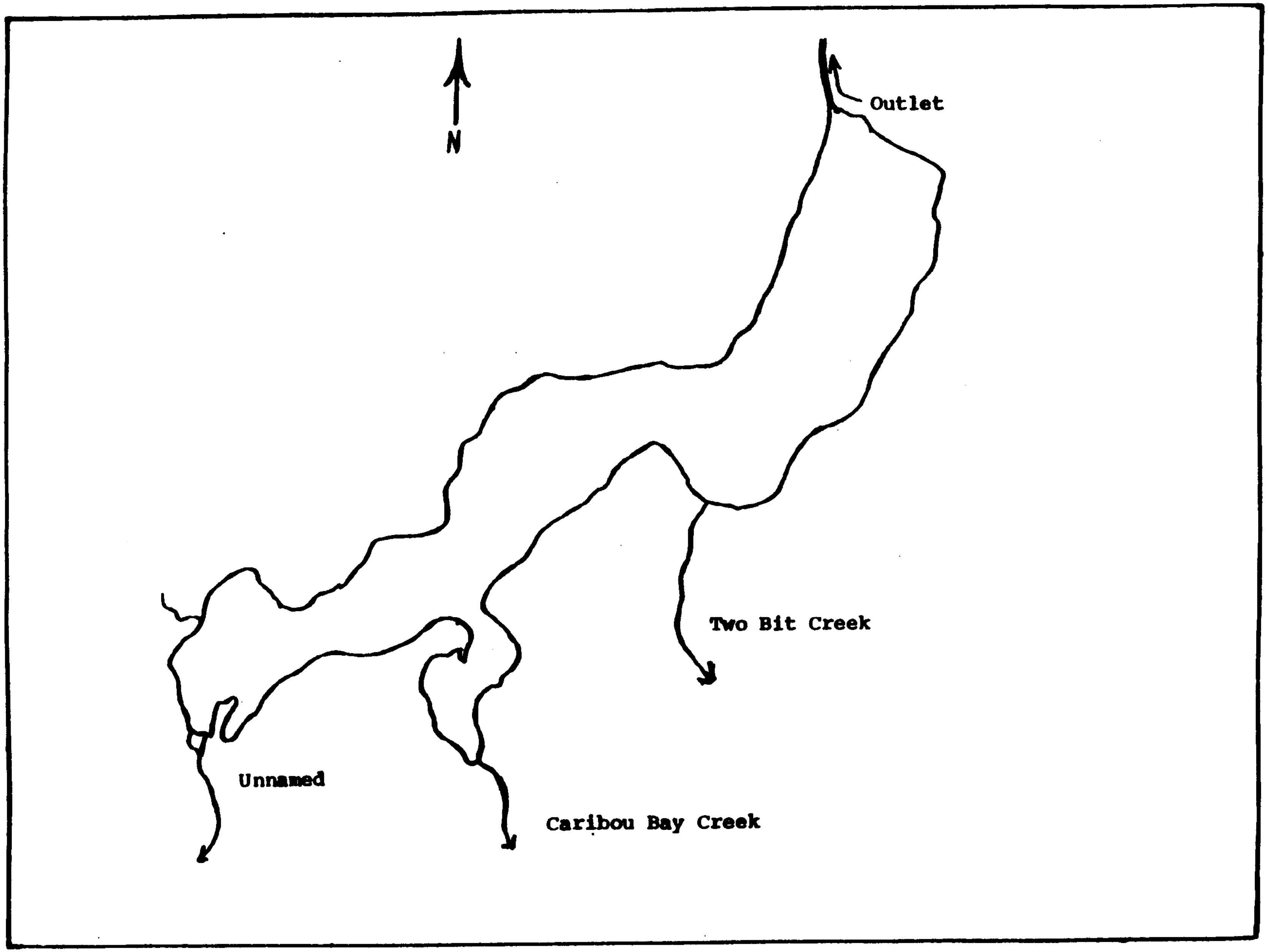

Figure 4. Fielding Lake and its tributaries.

5) all marked grayling are reported when recovered in the second sample.

Although these assumptions are stated for a two-sample experiment (Petersen type point census), they can readily be extended to multiple-sample experiments such as the modified Schnabel estimator by replacing "first sample" and "second sample" with "previous sample" and "subsequent samples". When a Jolly-Seber estimator is used, the assumption of closure can be relaxed, i.e. the population can be demographically open (mortality, recruitment, immigration, and emigration can occur). Geographic closure of the population must occur for any of these estimators to be valid (White et al. 1982).

The analysis of capture/recapture data was performed in two steps. First, the data were grouped according to somewhat (although not always) arbitrary length categories. These frequency data were then subjected to two statistical tests of assumptions necessary for estimating absolute abundance. The first test involved a chi-squared contingency table analysis of the frequencies of those fish recaptured by length category versus those not recaptured by length category (Seber 1982). The hypothesis tested was: the probability of capture of marked fish was the same as that of unmarked fish among all sizes of fish. If we failed to reject this hypothesis, then the data did not need to be stratified into length categories.

The chi-squared contingency table test is not an exact test, therefore, in cases where the capture probabilities did not show an obvious trend (i.e., increasing or decreasing probability of capture among length categories) or the test was marginally nonsignificant, an exact test was used to detect changes in capture probability. The exact test used was the Kolmogorov-Smirnov two-sample test (Conover 1980), comparing the length distribution of recaptured fish with that of fish not recaptured in the second sample.

The second test involved a chi-squared contingency table analysis of the frequencies of those fish examined as marked by length category versus those examined as unmarked by length category (Seber 1982). The hypothesis tested was: recruitment had not changed the probability of capture of marked fish relative to unmarked fish in the recapture sample. As in the first test of assumptions, a Kolmogorov-Smirnov two-sample test was substituted if an exact test statistic was warranted. Alternatively, since we had the individual lengths of fish when captured and when recaptured, a nonparametric method of testing for recruitment and adjusting the abundance estimate for bias due to recruitment was used (Robson and Flick 1965).

These first steps were performed on all single and multiple-sample estimates of abundance. The second step was to choose the appropriate estimator for each of the abundance estimates. The following data analyses illustrate the second step for each of the specific water bodies.

<u>Chena River</u>. Absolute abundance of grayling in each of the four 3.2-km sample areas of the Lower Chena were estimated by first creating a data file of capture histories of all sampled fish. These files were then used as input into program CAPTURE. None of the four sample areas required stratification by length category, so that the capture history data files contained all data

from a particular sample area. Absolute abundance of grayling in the Lower Chena was estimated by a stratified design, with subsections "A" and "B" as strata and the two sample area abundance estimates in each stratum as samples (Cochran 1967):

$$(1) \qquad \hat{N}_i = R_i \cdot \bar{\hat{N}}_i$$

where: $\hat{N}_i$ = the estimated abundance in stratum (sublocation) i;
R_i = the possible number of sample areas in stratum i;

$$\bar{\hat{N}}_i = \frac{\sum_{j=1}^{r} \hat{N}_{ij}}{r}; \; r = 2 \text{ (3.2-km sample areas)};$$

$\hat{N}_{ij}$ = the abundance of grayling in sample area j of stratum i;
i = 1, 2 strata; and,
j = 1, 2 3.2-km sample areas.

Subsection "A" had 12.5 possible 3.2-km sample areas (R_1 = 12.5) and subsection "B" had 10 possible 3.2-km sample areas (R_2 = 10). The variance of each subsection abundance estimate was calculated as follows:

$$(2) \qquad \hat{V}(\hat{N}_i) = R_i[R_i - r]\, \hat{S}^2 + \frac{R_i^2}{r^2} \sum_{j=1}^{r} \hat{V}(\hat{N}_{ij})$$

where: $\hat{V}(\hat{N}_i)$ = variance of grayling abundance in stratum i;

$$\hat{S}^2 = \frac{\sum_{j=1}^{r} (\hat{N}_{ij} - \bar{\hat{N}}_i)^2}{r(r - 1)};$$

$\hat{V}(\hat{N}_{ij})$ = variance of grayling abundance in sample area j of stratum i (from program CAPTURE); and,
r = the number of 3.2-km areas sampled.

The two strata (subsection) abundance estimates and variances are statistically independent of one another. Therefore, the strata estimates were simply added together to estimate the abundance and variance in abundance of grayling in the Lower Chena:

$$(3) \qquad \hat{N}_L = \sum_{i=1}^{2} \hat{N}_i \quad \text{and} \quad \hat{V}(\hat{N}_L) = \sum_{i=1}^{2} \hat{V}(\hat{N}_i)$$

where: $\hat{N}_L$ = the abundance of grayling in the Lower Chena; and,

$V(\hat{N}_L)$ = variance of abundance of grayling in the Lower Chena.

The estimate of grayling abundance in the Upper Chena was performed as a modified Petersen estimate that was stratified by length category. The three length categories chosen, based on chi-squared analysis, were 150 to 249 mm FL, 250 to 299 mm FL, and greater than 299 mm FL. Since each of the length category abundance estimates were statistically independent of one another, the estimate of grayling abundance in the Upper Chena was calculated as the sum of these three independent estimates. Variance of grayling abundance in the Upper Chena was also calculated as the sum of the three length category variances. Variances of the three length category abundance estimates were estimated by bootstrap methods (Efron 1981). The capture histories of all grayling sampled, by length category, were randomly resampled and the modified Petersen estimate simulated 1,000 times. Variance of the 1,000 simulations of the estimate was calculated by the standard variance formula (Snedecor and Cochran 1980).

The fact that stratification of the capture/recapture data was necessary implied that samples of grayling taken with the electrofishing boat were biased with respect to the actual abundance of grayling in the Upper Chena. Bias in abundance estimation, due to length selectivity of the capture gear, was corrected for by stratifying the capture/recapture data as shown above. However, bias in age and size composition remained uncorrected. The correction of age and size composition estimates was performed during bootstrapping of the length category capture histories. Methods of calculation are presented in the Estimation of Age Composition section of this report.

An estimate of absolute abundance of grayling in the lower 152 km of the Chena River was calculated by summing the independent estimates from Lower and Upper Chena sections. Variance of this estimate was calculated by summing the independent variances from Lower and Upper Chena sections.

Richardson Clearwater River. The grayling abundance estimates were calculated by bootstrapping the multiple-sample experiments 1,000 times each. Variance of these estimates was calculated with the standard variance formula. The modified Schnabel formula was used as the abundance estimator during bootstrapping. The estimate of grayling abundance in the Richardson Clearwater River was calculated as the sum of the river section abundance estimates.

No significant difference in size composition was found between samples taken in July and samples taken in August. Therefore, data collected during all six sample events were included in the abundance estimates. Significant differences were found between the size composition of the marked and unmarked populations of grayling. Based on chi-squared analysis, two length categories were chosen for separate abundance estimation: 250 to 349 mm FL and greater than 349 mm FL. Data collected from grayling of 200 to 249 mm FL range were excluded from the estimates, primarily due to the low density and difficulty in recapturing grayling of this size range. Due to insufficient numbers of recaptures in section 1, data collected in sections 1 and 2 were combined. Abundance was estimated separately in section 3.

Goodpaster River. The two grayling abundance estimates were calculated with program CAPTURE. Based on chi-squared analysis of length selectivity, neither of the two 4.8-km river section abundance estimates required length stratification. Each of the two data files containing capture histories of all fish greater than 199 mm FL were run through program CAPTURE to examine these data for departures from assumptions necessary to multiple capture/recapture estimation of abundance. The abundance of grayling from 150 to 199 mm FL was estimated by the modified Schnabel formula and then added to the program CAPTURE estimates of grayling greater than 199 mm FL.

Shaw Creek. The absolute abundance of grayling in Shaw Creek during 1986 was estimated with the generalized Jolly-Seber (Jolly 1965, Seber 1965) model. Grayling captured during electrofishing were examined for tags that were implanted between 1980 and 1986 at the Caribou Creek weir. Using the number of grayling tagged, by year, and the number of grayling recaptured in following years, an estimate of abundance, mortality, and recruitment was calculated. The addition of 1987 data to the Jolly-Seber model also affects the population estimates from the years 1981 to 1985, so that these estimates are also presented in the results section below.

Alternatively, an estimate of grayling abundance in April of 1987 was estimated by the modified Petersen estimator. During recapture of grayling for estimation with the Jolly-Seber estimator, unmarked grayling were tagged and released. As post spawning grayling departed Caribou Creek to summer feeding areas, they were captured by weir trap and examined for marks (either tagged in April of 1987 or examined as tagged during the same time period). Due to low numbers of recaptured grayling, no chi-squared analysis could be performed to detect length selectivity of the electrofishing boat during marking. Variance of this estimate was calculated with a formula developed by Seber (1970) and Wittes (1972).

Fielding Lake. The absolute abundance of grayling in Fielding Lake was estimated with Chapman's (1951) modification of the Petersen estimator. Significant recruitment of grayling less than 200 mm FL into the population occurred between marking (June) and examining for marks (August). To correct for recruitment, some of the fish examined for marks in August were culled from the capture/recapture data file (see Robson and Flick 1965 and Seber 1982).

Estimation of Relative Abundance

In 1986 estimates of electrofishing CPUE were developed to index the relative abundance of grayling in the Delta Clearwater and Richardson Clearwater Rivers (Clark and Ridder 1987b). Although this method of indexing abundance has been used on the Delta Clearwater River since 1975 and the Richardson Clearwater River since 1977, no estimates of the sampling variance of CPUE had been developed until 1986. The assumption was made that CPUE of electrofishing is proportional to the absolute abundance of grayling in these rivers. Ridder (1985) found that electrofishing catches in a 3.2-km section of the Richardson Clearwater River accurately estimated relative abundance of grayling in that river. Although no recent absolute abundance data are available for grayling in the Delta Clearwater River, it was presumed that electrofishing catches would also accurately estimate abundance in this river.

In 1986, the precision of relative abundance estimates was investigated with bootstrapping techniques as developed by Efron (1982). This technique proved valuable as a tool for calculating variances and confidence intervals for estimates of electrofishing CPUE. Due to the success of this technique, bootstrapping was used to calculate CPUE, the sampling variance of CPUE, and confidence intervals of CPUE in the Delta Clearwater and Richardson Clearwater Rivers in 1987. With absolute and relative abundance estimates, we will be able to test the accuracy of electrofishing CPUE in the Richardson Clearwater River.

Delta Clearwater Study Design:

Between 6 and 16 July, two 4.8-km sections of the Delta Clearwater River were sampled with a boat-mounted AC electrofishing system (three crew members). The furthest downstream of these two river sections extends from river kilometer 6.4 to river kilometer 11.2. The river is approximately 15 to 23 m wide in this section. The upper river section extends from river kilometer 22.4 (the junction of the left and right forks of the Delta Clearwater River) to approximately river kilometer 27.6 (locally known as the "upper lake"). The upper section is approximately 8 to 11 m wide. Every other day, the two 4.8-km sections were each sampled once with the electrofishing system.

All grayling captured were measured for length, scale sampled, and released throughout the section. Sampling was continued for five sampling runs in the 2 week period, using identical capture method and sampling crew. The total number of fish caught ($\geq$ 150 mm FL) during each sampling run and time expended capturing grayling were recorded. Catch rate (CPUE) was defined as the number of grayling greater than 149 mm FL captured per single pass of the electrofishing boat through each of the two 4.8-km sections.

Richardson Clearwater Study Design:

Sampling was conducted in conjunction with the absolute abundance estimation described earlier. The same river sections and gear types used for estimation of absolute abundance were used for estimation of relative abundance. On a given day, one electrofishing run was made through each of the sections. CPUE statistics were collected in the same manner as the Delta Clearwater River study design. The time of each run was recorded to the nearest 1 minute. Catch rate data from only three of the six possible sampling events (conducted from 7 to 17 July and on 3 August) were used to estimate relative abundance. Data collected during the first sampling event were excluded due to the testing of a new electrode design. Data collected during the last two sampling events were excluded due to the use of DC electrofishing gear. Changes in electrofishing electrode design and electrical current type may have affected the efficiency of the electrofishing boat, thereby affecting the catchability and catch rate of the gear. Changes in catch rate, due to factors other than changes in the abundance of grayling, would have tended to bias the estimates of relative abundance (Ricker 1975).

Data Analysis:

The bootstrap mean CPUE was approximated by Monte Carlo methods, randomly sampling the mean of 5 data points (with replacement) 1,000 times as follows:

$$(4) \qquad CPUE_B = \frac{\sum_{j=1}^{B} \left\{ CPUE_j = \left[\sum_{i=1}^{5} C_{Bi} \right] \div 5 \right\}}{B}$$

where: B = the number of bootstrap samples (1,000 in this case);
i = 1, 2, 3, 4, 5 random draws from the 5 original data points (with replacement);
C_{Bi} = the ith random draw from the original data;

$CPUE_B$ = the bootstrap mean catch rate; and,
$CPUE_j$ = the catch rate of the jth bootstrap iteration (i.e., a bootstrap sample).

The bootstrap variance was approximated by the standard variance formula:

$$(5) \qquad V(CPUE_B) = \left[\sum_{j=1}^{B} (CPUE_j - CPUE_B)^2 \right] \div (B - 1)$$

where: $V(CPUE_B)$ = the bootstrap variance of $CPUE_B$.

A nonparametric 95% confidence interval was estimated for $CPUE_B$ by the percentile method of Efron (1981). Bootstrap mean CPUE was calculated for the two river sections of the Delta Clearwater River and the three river sections of the Richardson Clearwater River. In addition, CPUE estimates with the combined data sets for a particular river were also calculated.

Estimation of Mean Length at Age and Age Composition

Estimates of the mean length at age were used to characterize growth of grayling in nine waters of the Tanana drainage in 1987. In addition to characterizing growth of grayling in the nine study waters, the proportion of the grayling stock represented in each age class was estimated. Age class composition was used to apportion abundance estimates by age class.

It is known that some types of sampling gear can introduce bias into estimates of absolute abundance by means of length selectivity (Ricker 1975). Length selectivity also introduces bias into age class composition estimates and estimates of size composition, such as the Relative Stock Density indices of

Gablehouse (1984). Removal of bias in age and size composition estimates was accomplished by means of capture/recapture experiments, in conjunction with estimation of absolute abundance. The recapture-to-mark ratios from the length category subsets (from abundance estimation) were used to adjust the number of fish sampled at age that were also within the length range of the length category (Laarman and Ryckman 1982). More specific methodology for correcting for bias in age composition estimates is given in the following Data Analysis section.

Chena River Study Design:

Collections of grayling for age-length samples were conducted in conjunction with abundance estimation experiments. The Lower Chena age-length samples are analyzed independently of the Upper Chena age-length samples. The age composition estimates were used to apportion the abundance estimates into age specific components. The resulting estimates of abundance at age were then summed across areas (Lower and Upper Chena) to estimate the age composition of grayling in the lower 152 km of the Chena River.

Chatanika River Study Design:

Collection of grayling for age-length samples was conducted in conjunction with tagging of whitefish species during the Interior Whitefish Research Project (Hallberg in prep.). Age-length sampling of the Chatanika River grayling stock was conducted from 10 to 13 August on a 16 km stretch of river upstream and downstream of the Elliot Highway Bridge. All grayling greater than 149 mm FL were tagged with Floy internal anchor tags and released near the capture site. No capture/recapture experiments were conducted to determine if bias due to length selectivity occurred during sampling. The age class composition of the Chatanika River grayling stock was adjusted for bias by using the same length categories and applying the same capture probabilities (recapture-to-mark ratios) as determined from the Upper Chena capture/recapture experiment on the Chena River in 1987.

Salcha River Study Design:

Age-length sampling and tagging of the Salcha River grayling stock was conducted from 1 to 10 June. Sampling operations were conducted along the lower 40 km of the river during a time when grayling were known to be migrating from spawning to feeding areas. The entire 40 km stretch was sampled with a pulsed-DC electrofishing boat at least once. Specific stretches were sampled more then once when the abundance of grayling was high enough to permit additional sampling. All grayling greater than 149 mm FL were tagged with Floy internal anchor tags and released near the capture site. Grayling caught more than once (tag recaptures) were not sampled for age and length after the second capture. No capture/recapture experiments were conducted to determine if bias due to length selectivity occurred during sampling. Age class composition was adjusted for bias with the length categories and capture probabilities as determined from the Upper Chena.

Delta Clearwater Study Design:

Age-length sampling of grayling in the Delta Clearwater River was conducted in conjunction with relative abundance estimation from 6 to 16 July. Grayling thought to have been previously sampled for age (freshly missing scales in the preferred zone) were considered recaptures and not sampled. Due to the lack of sufficient samples for estimation of age composition, additional sampling was conducted with a DC electrofishing boat from river kilometer 16 to the river mouth during 3 September. Age-length samples were also collected with a 15 m beach seine (15 m x 2 m, with 10 mm mesh) during 28 August and during 1 September. Seine hauls were performed in riffle areas along river kilometers 4.8 to 13.3.

Richardson Clearwater Study Design:

Age-length samples were collected along the lower 12.8 km of the Richardson Clearwater River in conjunction with abundance estimation in July and August. Recaptured grayling were not sampled for age and length a second time.

Goodpaster River Study Design:

Collection of grayling for age-length samples was conducted during abundance estimation in the two previously described 4.8-km sections. All grayling greater than 149 mm FL were sampled for age and length, with recaptured fish sampled only once.

Shaw Creek Study Design:

Age-length samples were collected during marking and recapture runs in the abundance estimation experiment 1.6 km above and below the mouth of Shaw Creek in the Tanana River. Sampling was performed during the prespawning migration (15 to 23 April), enabling sex determination to be made. All grayling captured were anesthetized with MS-222 (tricaine methanesulfonate) before an age-length sample was taken. Grayling recaptured during the experiment were not resampled. Sex was determined by examination of morphological characteristics (enlarged vent in females and elongated dorsal fin in males) and by the presence of milt or eggs.

Caribou Creek Study Design:

Caribou Creek is considered the most important of two known spawning tributaries of Shaw Creek. During the first 2 weeks in June, post-spawning and sub-adult grayling depart Caribou Creek to summer feeding streams (Ridder 1982). Since 1980, these grayling have been captured at a weir trap located near the mouth of Caribou Creek. In addition to age-length sampling, all grayling greater than 199 mm FL are tagged with internal anchor Floy tags.

In 1987, sampling was conducted from 3 to 11 June. In addition to passive capture of grayling by weir trap, grayling were also herded into the weir trap with a beach seine (50 m x 2 m, with 10 mm mesh). Due to low water conditions, herding was necessary to force grayling into the trap. All captured grayling were anesthetized with dissolved CO_2 prior to sampling, and those fish greater than 199 mm FL were tagged with Floy internal anchor tags. Sex was determined by examination of body morphology.

Fielding Lake Study Design:

Collection of grayling for age-length samples was conducted at Fielding Lake in conjunction with abundance estimation. During the first phase of marking at Fielding Lake (16 to 21 June), all fish greater than 199 mm FL were anesthetized with dissolved CO_2 and sampled for age, length, and sex. No age data were taken during the second phase of sampling (20 to 25 August).

Tangle Lakes System Study Design:

Collection of age-length samples was conducted in the Tangle Lakes system in late June and again in late August. Electrofishing was conducted on Upper and Round Tangle lakes in June with a boat mounted DC electrofishing system employing a crew of three (Figure 5). A 15 m x 2 m beach seine, with 10 mm meshes, was used to collect grayling in the Tangle River (between upper and Round Tangle lakes) during the two time periods (June and August). The thoroughfares connecting Round, Shallow, and Long Tangle lakes, and the section of 18 Mile Creek bisecting the Denali Highway were seined for grayling with the same gear in June. With the exception of the Tangle River, all areas were sampled only once. The Tangle River was systematically seined from Upper Tangle Lake downstream to its mouth at Round Tangle Lake twice in both June and August. A 270 m x 3 m purse seine, with 25 mm meshes, was also used to collect grayling in Round Tangle Lake at the mouth of the Tangle River during one evening in June. Scale samples were collected from 20 grayling in each 20 mm length group below 200 mm FL and from all grayling 200 mm FL and greater. Grayling were not anesthetized before age-length sampling.

Data Collection:

In all of the water bodies discussed above, grayling were measured to the nearest 1 mm FL and a scale smear (at least 2 scales) was taken from the area approximately six rows above the lateral line just posterior to the insertion of the dorsal fin. Scales were processed by cleaning in a solution of hydrolytic enzyme (BIZ detergent) and then mounting two scales from each fish on gum cards. These gum cards were used to make impressions of the scales on triacetate film (30 seconds at 7,000 kg/cm^2, at a temperature of 100°C). Ages were determined by replicate readings of the triacetate impressions with a microfiche reader.

Data Analysis:

The proportion of grayling in each age class was estimated as:

$$(6) \qquad \hat{p}_i = \frac{y_i}{n}$$

where: y_i = the number of grayling of age i in the sample; and,
n = the number of grayling in the sample.

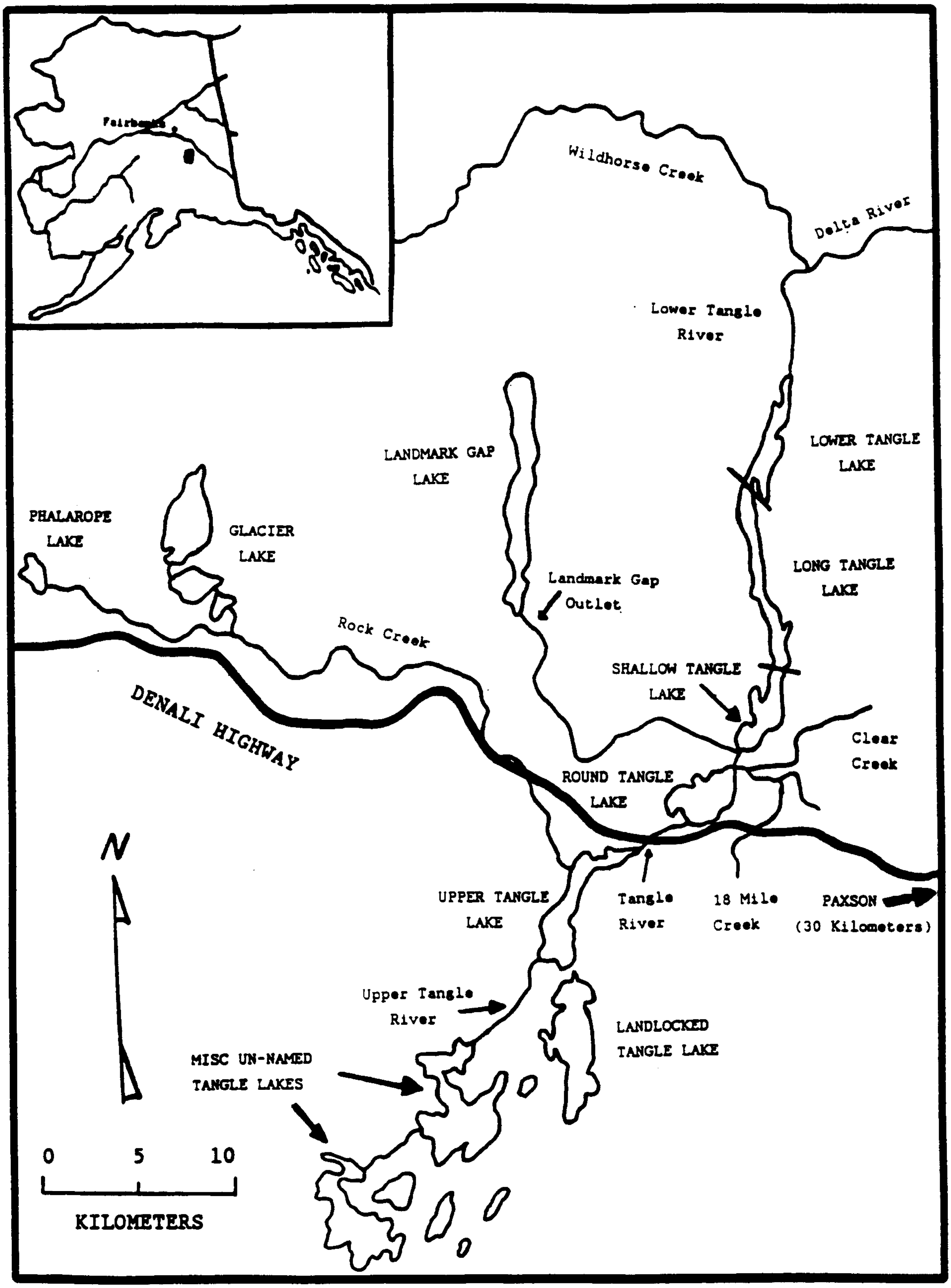

Figure 5. The Tangle Lakes system.

The unbiased variance of this proportion was estimated as:

(7) $$\hat{V}[\hat{p}_i] = \frac{\hat{p}_i (1 - \hat{p}_i)}{n - 1}$$

Mean length at age was calculated by the arithmetic mean of all fish lengths assigned the same age. Variances were calculated with the squared deviations from the mean (standard variance formula).

Age class composition of grayling stocks for which a capture/recapture experiment had been performed were adjusted for bias due to length selectivity of the capture gear or gears. These adjustments were made only if significant bias was detected from chi-squared or Kolmogorov-Smirnov tests as detailed above. After determining the suitable number of subset length categories for independent abundance estimation, the recapture-to-mark ratio was used as a measure of the capture probability in the particular subset of the capture/recapture data (Laarman and Ryckman 1982). For example, with the Upper Chena data set there were three length categories used to adjust for length selectivity. Each of these three subsets of the data had a capture probability associated with it, defined as:

(8) $$CP_j = \frac{RECAP_j}{MARK_j}$$

where: CP_j = the capture probability of grayling in length category j;
$RECAP_j$ = the number of recaptured grayling in length category j; and,
$MARK_j$ = the number of marked grayling in length category j.

There were three capture probabilities in the Upper Chena data set, from length category 1 (150 to 249 mm FL), length category 2 (250 to 299 mm FL), and length category 3 (greater than 299 mm FL). The number of grayling actually sampled that were of age i and in length category j were adjusted with the ratio of the largest capture probability to the capture probability in length category i:

(9) $$\hat{x}_{ij} = \frac{CP_L}{CP_j} n_{ij}$$

where: $\hat{x}_{ij}$ = the adjusted number of grayling of age i that were also in length category j;
CP_L = the highest capture probability among all j length categories;
CP_j = the capture probability of grayling in length category j, regardless of their age; and,
n_{ij} = the actual number of grayling of age i that were also in length category j.

In the Upper Chena section, j equalled 3 length categories and i was 9 age classes. The result of this adjustment was that all length categories with low capture probabilities ($CP_j < CP_L$) were adjusted upward. The length category with the highest capture probability was not adjusted ($CP_L/CP_L = 1$). Adjusted age composition was calculated by summing the adjusted numbers of grayling of age i, regardless of length category, and performing the age proportion calculation of equation 6.

Estimation of variances of the adjusted age proportions was complicated by the fact that the capture probabilities have a variance and the sampled age proportions also have a variance. Because of the difficulties in deriving variances from the product of two random variables that have unknown distributions, variance of adjusted age proportion was approximated with bootstrap methods. To simplify the bootstrap procedure, the abundance estimation experiment and age composition adjustments were performed at the same time. The capture/recapture experiment was simulated 1,000 times, using the length, age, and capture history of each sampled grayling to estimate:

1) abundance and variance by length category;
2) capture probability and variance by length category;
3) adjusted age composition and variances; and,
4) adjusted Relative Stock Density and variances.

If capture probabilities were not estimated, such as the Chatanika River and Salcha River data sets, the capture probabilities from a capture/recapture experiment on a grayling stock with a similar length distribution and identical capture methods were used to make the adjustment to age composition statistics. For the Salcha and Chatanika River data collections, the Upper Chena capture probabilities were used. There were too few age-length samples taken from the Delta Clearwater River to make age composition adjustments, although the Richardson Clearwater River data set would have otherwise been used to perform adjustments. The Tangle Lakes system data set was sampled primarily with beach seines targeting on juvenile grayling. The Fielding Lake data set would have been used to adjust Tangle Lakes age composition estimates if the electrofishing boat had been used and larger grayling had been sampled. The Tangle Lakes age composition estimates were reported as unadjusted estimates, as were the Delta Clearwater River estimates.

In the case of the Salcha and Chatanika River data sets, the numbers of sampled grayling were adjusted by the ratio of capture probabilities for the Upper Chena as described in equation 9. The calculation of variances could not be performed with the same bootstrap methods as presented above, because the underlying distribution of the capture probabilities from the Upper Chena were not known. Instead of simulating the ratio of capture probabilities by bootstrap methods, the estimates of capture probabilities and variances were used directly from bootstrap calculations on the Upper Chena data set. However, the estimates and variance of grayling sampled at age that are also of a certain length category were simulated 500 times as in the bootstrap methods presented above.

First, the capture probabilities from the Upper Chena capture/recapture experiment were converted to adjustment factors as in equation 9:

$$(10) \qquad \hat{A}_j = \frac{CP_L}{CP_j}, \text{ for all } j \text{ (three length categories)},$$

where: $\hat{A}_j$ = the adjustment factor for all sampled grayling of length category j, regardless of age; and,
CP_L and CP_j are defined in equation 9.

The variance of the ratio of two independent variables (A_j) was approximated by the delta method (Seber 1982) as:

$$(11) \qquad V[\hat{A}_j] = \frac{CP_L^{\,2}}{CP_j^{\,2}} \left[\frac{V[CP_L]}{CP_L^{\,2}} + \frac{V[CP_j]}{CP_j^{\,2}} \right]$$

where: $V[\hat{A}_j]$ = the variance of the adjustment factor for length category j;
$V[CP_L]$ = the variance of the largest capture probability among the j length categories; and,
$V[CP_j]$ = the variance of the capture probability for length category j.

Next, the numbers of sampled grayling at age i and also in length category j were multiplied by the adjustment factor for length category j:

$$(12) \qquad \hat{x}_{ij} = \hat{A}_j \cdot \hat{n}_{ij}$$

where: $\hat{x}_{ij}$ = the adjusted number of grayling at age i that are also of length category j (as in equation 9);
$\hat{A}_j$ = the adjustment factor for length category j (from equation 10); and,
$\hat{n}_{ij}$ = the bootstrap number of sampled grayling at age i that are also of length category j.

The exact variance of the product of two independent variables was estimated by Goodman (1960) as:

$$(13) \qquad V[\hat{x}_{ij}] = (\hat{n}_{ij}^{\,2}\, V[\hat{A}_j]) + (\hat{A}_j^{\,2}\, V[\hat{n}_{ij}]) - (V[\hat{n}_{ij}]\, V[\hat{A}_j])$$

where: $V[\hat{x}_{ij}]$ = the variance of the adjusted number of grayling at age i that are also of length category j; and,
$V[\hat{n}_{ij}]$ = the bootstrap variance of the number of sampled grayling at age i that are also of length category j.

Lastly, the adjusted age composition was calculated by summing the adjusted numbers of grayling of age i (x_{ij}) and their variances ($V[x_{ij}]$), regardless of length category (j), and performing the age proportion calculation of equation 6. The variances of the adjusted proportions of grayling at age were approximated by the variance of the ratio of two dependent variables (Bernard 1983):

$$(14) \qquad \hat{V}[p_i] = \frac{\hat{V}[x_i]}{\hat{V}[X]} = \left[\frac{\hat{x}_i}{\hat{X}}\right]^2 \left[\frac{\hat{V}[x_i]}{\hat{x}_i^2} + \frac{\hat{V}[X]}{\hat{X}^2} - \frac{2\hat{V}[x_i]}{\hat{x}_i \cdot \hat{X}}\right]$$

where: $\hat{V}[p_i]$ = the variance of the adjusted proportion of grayling at age i;

$$\hat{V}[x_i] = \sum_{j=1}^{l} \hat{V}[x_{ij}]; \quad \hat{x}_i = \sum_{j=1}^{l} \hat{x}_{ij};$$

$$\hat{V}[X] = \sum_{i=1}^{a} \hat{V}[x_i]; \text{ and, } \quad \hat{X} = \sum_{i=1}^{a} \hat{x}_i;$$

l = the number of length categories used in stratification; and,
a = the number of age classes sampled.

The identical problem of bias due to length selectivity occurred in calculations of Relative Stock Density (RSD) indices. The solution to this problem was identical to that of age composition estimation. Instead of partitioning the data set by ages, it was partitioned by RSD categories as defined by Gablehouse (1984). For water bodies where a capture/recapture experiment was performed (e.g., Upper Chena), the bootstrap method was used for the adjustment of RSD estimates. The calculations for these analyses are detailed in equations 8 and 9. For water bodies where no capture probabilities were estimated (e.g, Salcha River), the adjustment of RSD estimates was calculated identically to the section above, except that RSD categories were substituted for age classes. The calculations for these analyses are detailed in equations 10 through 14. For water bodies that had no estimates of capture probabilities and no analogous water body from which to adjust RSD estimates (Delta Clearwater River and Tangle Lakes), the standard proportion and variance of a proportion calculations were used to estimate RSD. The calculations for these analyses are detailed in equations 6 and 7.

RESULTS AND DISCUSSION

Chena River

Abundance, age, and size composition estimates were performed on the Chena River stock between 29 June and 30 July. The Chena River was divided into two sections and separate estimates of the above parameters were estimated in each section. The section estimates were then combined to estimate the above parameters for the Chena River stock from river kilometer 152 to the mouth of the river.

Lower Chena Section:

Abundance estimation of grayling in the Lower Chena section of the Chena River was performed during 29 June to 3 July in subsection A and during 6 to 10 July in subsection B. River conditions were uniform during this period, with low water levels and extremely low levels of turbidity. The sample area estimates of grayling abundance ranged from 190 to 426 in a 3.2-kilometer stretch of river (Table 1). The highest abundance was observed in subsection A, averaging 395 grayling per 3.2 km of river (Table 2). Average abundance in subsection B was 213 grayling per 3.2 km of river. Model M_o, the null model, was chosen as most appropriate in three of the four program CAPTURE analyses (Table 1). Model M_t was chosen by program CAPTURE in one of the sample area estimates of subsection A. The null model is chosen if capture probabilities do not vary significantly during the course of the capture/recapture experiment. Model M_t is chosen if the capture probabilities vary significantly during the course of the experiment (White et al. 1982). No stratification of capture/recapture data by length category was indicated by either chi-squared analysis or program CAPTURE analyses.

The expanded estimate of grayling abundance in subsection A of the Lower Chena was 4,931 grayling or 123 grayling per km (Table 2). Expanding upon subsection B sample area estimates, the estimated number of grayling was 2,125 fish or 66 grayling per km. The estimate of grayling abundance in the entire 72 km of the Lower Chena section was 7,056 grayling (SE = 965 fish, CV[1] = 13.7%) or 98 grayling per km.

The estimated age composition of grayling (≥ 150 mm FL) in the Lower Chena did not require adjustment for length selectivity bias and therefore reflected the age composition of sampled grayling. Age-4 grayling dominated the Lower Chena sample. Of the 437 grayling sampled in the Lower Chena, 66% were age 4 (Table 3). Recruitment of age 3 grayling into the Chena River stock in the Lower Chena was poor in 1987. Only 11% of grayling sampled were age 3, while estimates of age 3 grayling in years of good recruitment have approached 75% of the Lower Chena sample (Hallberg 1982; Clark and Ridder 1987b). Apportioning the Lower Chena abundance estimate by age, the estimated recruitment in this section of the Chena River was 766 age 3 grayling (SE = 149 grayling, CV = 19.2%). No accurate determination of prerecruit abundance was possible, although low numbers of age 2 grayling indicated that recruitment will be poor in the summer of 1988 (see Holmes, et al. 1986 for a discussion of estimation of grayling recruitment).

Incremental RSD indices of Lower Chena grayling reflected the paucity of adult (≥ 270 mm FL) grayling in this section of the Chena River in July. Approximately 14% of grayling sampled were adult size, representing an estimated 967 potential spawners (SE = 165 spawners, CV = 17.1%) in 72.0 km of river. The remaining 86% of the Lower Chena sample were smaller than adult size (Table 4).

[1] CV = coefficient of variation of the estimate; the standard error of the estimate divided by the estimate, expressed as a percentage.

Table 1. Summary of sample area abundance estimates of grayling (≥ 150 mm FL) in the Lower Chena section of the Chena River, 29 June to 9 July 1987. The Lower Chena section is comprised of the lower 72 kilometers of the Chena River.

Subsection	River KM	CAPTURE Model[1]	Abundance Estimate	Standard Error	Fish/KM
A	12.8 - 16.0	M_t[2]	426	108	133
A	28.8 - 32.0	M_o[3]	363	85	113
B	44.8 - 48.0	M_o	190	20	59
B	56.0 - 59.2	M_o	235	21	73

1 Models selected by program CAPTURE (White et al. 1982) as most appropriate.

2 M_t is the time varying probability of capture model developed by Otis et al. (1978).

3 M_o is the null model with no change in probability of capture during the experiment (Maximum Likelihood estimate of Otis et al. (1978)).

Table 2. Estimated abundance of grayling (≥ 150 mm FL) in the lower 72 kilometers of the Chena River (Lower Chena section) in July of 1987.

Subsection	Subsection Length (KM)	Estimated Abundance	Variance	Standard Error
A	3.2	426	11,789	108
A	3.2	363	7,166	85
Average	3.2	395	992	32
Total	40.0	4,931	870,694	933
B	3.2	190	393	20
B	3.2	235	437	21
Average	3.2	213	506	23
Total	32.0	2,125	61,249	247
Lower Chena	72.0	7,056	931,942	965

Table 3. Estimates of sampled and adjusted[1] proportional contribution of each age class, sampled mean fork length (mm) at age, and standard errors for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the Lower Chena section of the Chena River stock, 29 June to 10 July 1987.

	Sampled:		Adjusted:		Fork Length:	
Age	n[2]	p[3]	p[4]	SE[5]	Mean[6]	SE[7]
2	7	0.016	0.016	0.006	141	5
3	48	0.110	0.110	0.015	193	3
4	289	0.661	0.661	0.023	217	1
5	53	0.121	0.121	0.016	262	4
6	19	0.043	0.043	0.010	286	5
7	21	0.048	0.048	0.010	297	7
Total	437	1.000	1.000		225	5

[1] Age composition is adjusted to compensate for bias in the electrofishing sample. The Lower Chena Section did not need to be adjusted, hence sample and adjusted values are the same.

[2] n = sample size.

[3] p = proportion of sampled grayling.

[4] p = adjusted proportion of grayling in stock.

[5] SE = standard error of the adjusted proportion.

[6] Mean = average fork length of all sampled grayling of a particular age (includes grayling < 150 mm FL).

[7] SE = standard error of the mean fork length.

Table 4. Summary of sampled and adjusted Relative Stock Density (RSD) indices for grayling (≥ 150 mm FL) in the Lower and Upper Chena sections and the entire lower 152 kilometers of the Chena River, July 1987.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
<u>Lower Chena</u>					
Number sampled	516	80	2	0	0
Sampled RSD[2]	0.863	0.134	0.003	---	---
Adjusted RSD[3]	0.863	0.134	0.003	---	---
Standard Error[4]	0.014	0.014	0.002	---	---
<u>Upper Chena</u>					
Number sampled	1,162	613	152	0	0
Sampled RSD	0.603	0.318	0.079	---	---
Adjusted RSD	0.755	0.204	0.041	---	---
Standard Error	0.045	0.043	0.008	---	---
<u>Chena River</u>					
Number sampled	1,678	693	154	0	0
Sampled RSD	0.665	0.274	0.060	---	---
Adjusted RSD	0.779	0.188	0.032	---	---
Standard Error	0.036	0.035	0.006	---	---

[1] Minimum lengths for RSD categories are (Gablehouse 1984):
Stock - 150 mm FL;
Quality - 270 mm FL;
Preferred - 340 mm FL;
Memorable - 450 mm FL; and,
Trophy - 560 mm FL.

[2] RSD calculated directly from the number sampled.

[3] RSD indices adjusted for bias due to length selectivity of the electrofishing boat.

[4] Standard error of adjusted RSD calculated by bootstrap methods.

Upper Chena Section:

Abundance estimation of grayling in the Upper Chena section of the Chena River was performed during 20 to 30 July. River condition during this period was similar to that of the Lower Chena section, although a rain storm during 24 and 25 July raised the water level and increased turbidity. Initial inspection of capture/recapture data revealed significant bias in capture probability due to length selectivity of the electrofishing boats (χ^2 = 7.55, df = 2, 0.010 < P < 0.025). The data were partitioned into three length categories to adjust for bias: small (150 to 249 mm FL); medium (250 to 299 mm FL); and, large (≥ 300 mm FL) size grayling. Capture probabilities among the three categories ranged from 0.029 recaptures per marked fish for small grayling to 0.074 for large grayling (Table 5). There was no evidence of significant recruitment between marking and recapture events (χ^2 = 0.02, df = 2, P > 0.975). The summed estimate of grayling abundance in the Upper Chena was 24,446 grayling (SE = 3,364 grayling, CV = 13.8%) or 306 grayling per km (Table 5).

The estimated age composition of Upper Chena grayling (≥ 150 mm FL) required adjustment for length selectivity bias. As a result of the adjustment technique, younger age classes were adjusted upward and older age classes were adjusted downward (Table 6). Bootstrap estimates of standard error of age proportions were larger than standard errors estimated with the binomial approximation (standard error of age proportions in 1986 were estimated using the binomial approximation, Clark and Ridder 1987b). The slightly larger standard errors are due to additional variation introduced from the capture probabilities used to adjust the sampled number of grayling at age (Table 5; Table 6). As with the Lower Chena age composition, the Upper Chena portion of the Chena River stock exhibited a strong age 4 component. In addition, the age 7 component represented 12% of grayling in the Upper Chena. The estimate of age 3 recruits in this section of the Chena River was approximately 1,760 grayling (SE = 326 grayling, CV = 18.5%) or 7% of the estimated abundance. Estimates of prerecruit abundance probably do not accurately reflect the true abundance of age 1 and age 2 grayling, but do indicate a low level of recruitment in 1988.

Adjusted incremental RSD indices of grayling in the Upper Chena section indicated that approximately 76% of the grayling in this section were smaller than adult size (Table 4). The estimate of adult size grayling in this section of the Chena River was 5,989 grayling (SE = 1,342, CV = 22.4%) or 24% of the estimated abundance. No memorable or trophy size grayling were captured during abundance estimation in the Upper Chena.

Chena River Sections Combined:

The combined Lower and Upper Chena estimate of grayling abundance was 31,502 fish (SE = 3,500, CV = 11.1%) or 207 grayling per km. This estimate represented a decline of approximately 49% from the 1986 estimate (N = 61,581 grayling, SE = 26,987). However, these two abundance estimates were not significantly different (z = -1.11, P > 0.36) due to imprecision in the 1986 estimate. Regardless of the significance of this comparison, it must be noted that the population of grayling may have decreased from 1986 to 1987 and that

Table 5. Capture probabilities and estimated abundance in three length categories used for population estimation of grayling (≥ 150 mm FL) in the Upper Chena section of the Chena River, 20 to 30 July 1987.

Length Category	Mark n_1	Catch n_2	Recap m	CP[1]	SE[CP][2]	$\hat{N}$[3]	SE[$\hat{N}$][4]
150 to 249	479	500	14	0.029	0.006	16,542	2,885
250 to 299	214	236	12	0.054	0.018	4,489	1,440
≥ 300	229	252	17	0.074	0.017	3,415	956
Total	922	988	43	---	---	24,446	3,364

[1] CP is the probability of capture determined from bootstrap methods.

[2] SE[CP] is the standard error of CP determined from bootstrap methods.

[3] N is the estimated abundance in a length category, determined from bootstrap methods.

[4] SE[N] is the bootstrap standard error of N.

Table 6. Estimates of sampled and adjusted[1] proportional contribution of each age class, sampled mean fork length (mm) at age, and standard errors for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the Upper Chena section of the Chena River, 20 to 30 July 1987.

	Sampled:		Adjusted:		Fork Length:	
Age	n[2]	p[3]	p[4]	SE[5]	Mean[6]	SE[7]
1	3	0.004	0.003	0.002	127	6
2	37	0.045	0.058	0.012	165	4
3	42	0.051	0.072	0.009	207	4
4	402	0.485	0.589	0.034	231	1
5	62	0.075	0.062	0.014	277	4
6	57	0.069	0.049	0.013	293	3
7	163	0.197	0.122	0.020	312	2
8	30	0.036	0.023	0.007	324	5
9	31	0.037	0.020	0.004	338	5
10	2	0.002	0.001	0.000	353	7
11	2	0.002	0.001	0.000	371	29
Total	831	1.000	1.000		258	2

1 Age composition is adjusted to compensate for bias in the electrofishing sample. Bootstrap methods were used to estimate adjusted proportions and standard errors.

2 n = sample size.

3 p = proportion of sampled grayling.

4 p = adjusted proportion of grayling in stock.

5 SE = standard error of the adjusted proportion.

6 Mean = average fork length of all sampled grayling of a particular age (includes grayling < 150 mm FL).

7 SE = standard error of the mean fork length.

this decrease could be due to poor recruitment into the stock. The combined estimate of age 3 recruits in the Chena River was 2,526 grayling (SE = 358, CV = 14.2%), representing only 8% of the stock (Table 7). The combined forces of natural and fishing mortality remove approximately 45% of the stock each year (Holmes et al. 1986), so that 2,526 age 3 grayling would not have replaced the debit in grayling abundance due to mortality. Indications from the abundance of age 2 grayling in the Chena River were that recruitment in 1988 would be low and that an additional decrease in population size would be expected.

Adjusted incremental RSD indices reflected the shift in age, and therefore size composition that occurred between 1986 and 1987. Stock RSD in the Chena River declined from 87% in 1986 to 78% in 1987, while the proportion of adult size grayling increased from 13% in 1986 to 22% in 1987 (Table 4; Clark and Ridder 1987b). The estimate of adult size grayling in the Chena River in 1987 was 6,930 fish (SE = 1,352 grayling, CV = 19.5%) or 22% of the estimated abundance.

Chatanika River

Estimation of age and size composition of the Chatanika River grayling stock was performed during 10 to 13 August. No capture/recapture experiment was performed to determine abundance or capture probabilities of marked fish. It was presumed that bias due to length selectivity of the electrofishing boat was present in the size and age sample from the Chatanika River. Assuming that probabilities of capture by electrofishing were similar between the Chatanika River and Upper Chena section, adjustment factors for the Upper Chena section of the Chena River were used to adjust for bias in the Chatanika River sample.

The sample of Chatanika River grayling consisted of 553 fish greater than 149 mm FL. Ages of sampled grayling ranged from age 2 to age 10, with the majority of the sample represented by age 4 and age 7. Age 4 grayling represented 63% of the stock, while age 7 grayling represented 12% of the stock (Table 8). Eleven percent of the stock was age 3, indicating a low level of recruitment in 1987. Although absolute abundance was not estimated, the level of recruitment in the Chatanika appears similar to the Chena River stock. The patterns of recruitment in these two stocks have tended to parallel each other, indicating similar patterns of environmental perturbation as was shown by Holmes et al. (1986).

Adjusted incremental RSD indices indicated a low proportion of adult size grayling in the Chatanika River. Fourteen percent of the Chatanika River stock was adult size, while 21% of the Chena River stock was adult size (Table 9).

Salcha River

Estimation of age and size composition of the Salcha River grayling stock was performed during 1 to 10 June. No capture/recapture experiment was performed to determine abundance or capture probabilities of marked fish. It was presumed that bias due to length selectivity of the electrofishing boat was

Table 7. Estimates of sampled and adjusted[1] proportional contribution of each age class, sampled mean fork length (mm) at age, and standard errors for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the Chena River stock, 29 June to 30 July 1987.

	Sampled:		Adjusted:		Fork Length:	
Age	n[2]	p[3]	p[4]	SE[5]	Mean[6]	SE[7]
1	3	0.002	0.002	0.002	127	6
2	44	0.035	0.049	0.011	164	4
3	90	0.071	0.081	0.011	201	3
4	691	0.545	0.605	0.032	225	1
5	115	0.091	0.075	0.014	270	3
6	76	0.060	0.048	0.012	291	3
7	184	0.145	0.105	0.018	310	2
8	30	0.024	0.018	0.006	324	5
9	31	0.024	0.016	0.004	338	5
10	2	0.002	0.001	0.000	353	7
11	2	0.002	0.001	0.000	370	29
Total	1,268	1.000	1.000		259	4

1 Age composition is adjusted to compensate for bias in the electrofishing sample. Bootstrap methods were used to estimate adjusted proportions and standard errors.

2 n = sample size.

3 p = proportion of sampled grayling.

4 p = adjusted proportion of grayling in stock.

5 SE = standard error of the adjusted proportion.

6 Mean = average fork length of all sampled grayling of a particular age (includes grayling < 150 mm FL).

7 SE = standard error of the mean fork length.

Table 8. Estimates of sampled and adjusted[1] proportional contribution of each age class, sampled mean fork length (mm) at age, and standard errors for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the Chatanika River stock, 10 to 13 August 1987.

Age	Sampled: n^2	Sampled: p^3	Adjusted: p^4	Adjusted: SE^5	Fork Length: $Mean^6$	Fork Length: SE^7
2	11	0.020	0.024	0.010	157	5
3	50	0.090	0.108	0.035	200	3
4	295	0.533	0.626	0.075	228	1
5	32	0.058	0.050	0.016	265	4
6	47	0.085	0.058	0.022	273	3
7	106	0.192	0.121	0.039	288	3
8	8	0.014	0.007	0.004	319	6
9	3	0.005	0.004	0.002	296	55
10	1	0.002	0.001	0.001	325	---
Total	553	1.000	1.000		244	2

[1] Age composition is adjusted to compensate for bias in the electrofishing sample. Adjustment factors are taken from the Upper Chena abundance estimate.

[2] n = sample size.

[3] p = proportion of sampled grayling.

[4] p = adjusted proportion of grayling in stock.

[5] SE = standard error of the adjusted proportion.

[6] Mean = average fork length of all sampled grayling for a particular age (includes grayling < 150 mm FL).

[7] SE = standard error of the mean fork length.

Table 9. Summary of sampled and adjusted Relative Stock Density (RSD) indices for grayling (≥ 150 mm FL) in the Chena, Chatanika, and Salcha Rivers, June through August 1987.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
Chena River					
Number sampled	1,678	693	154	0	0
Sampled RSD[2]	0.665	0.274	0.060	---	---
Adjusted RSD[3]	0.779	0.188	0.032	---	---
Standard Error[4]	0.036	0.035	0.006	---	---
Chatanika River					
Number sampled	420	126	7	0	0
Sampled RSD	0.759	0.228	0.013	---	---
Adjusted RSD	0.857	0.136	0.006	---	---
Standard Error	0.049	0.048	0.003	---	---
Salcha River					
Number sampled	275	171	71	1	0
Sampled RSD	0.530	0.330	0.137	0.003	---
Adjusted RSD	0.689	0.230	0.080	0.001	---
Standard Error	0.073	0.065	0.028	0.001	---

[1] Minimum lengths for RSD categories are (Gablehouse 1984):
Stock - 150 mm FL;
Quality - 270 mm FL;
Preferred - 340 mm FL;
Memorable - 450 mm FL; and,
Trophy - 560 mm FL.

[2] RSD calculated directly from the number sampled.

[3] RSD indices adjusted for bias due to length selectivity of the electrofishing boat.

[4] Standard error of adjusted RSD calculated by bootstrap methods.

present in the size and age sample from the Salcha River. Assuming that probabilities of capture by electrofishing were similar between the Salcha River and Upper Chena section, adjustment factors for the Upper Chena section of the Chena River were used to adjust for bias in the Salcha River sample.

The adjusted age composition of grayling in the Salcha River stock was similar to the Chena River and Chatanika River stocks, excepting the presence of relatively strong age 5 and age 6 components in the stock (Table 10). Twenty percent of the Salcha River stock was age 5, while this age class represented 5% of the Chatanika River stock and 7% of the Chena River stock. Eleven percent of the Salcha River stock was age 6, while this age class represented 6% and 5% of the Chatanika River and Chena River stocks, respectively. The age 4 component of the Salcha River stock appeared relatively strong, as predicted by the discharge hypothesis of Holmes et al. (1986).

Higher proportions of older grayling found in the Salcha River stock also translated into larger grayling found in that stock, as indicated by the adjusted incremental RSD indices. The Salcha River stock had the smallest proportion of sub-adult grayling when compared to the Chatanika and Chena River stocks (Table 9). Thirty-one percent of the Salcha River stock were of adult size, whereas the Chatanika and Chena River stocks were comprised of 14% and 21% adult size grayling, respectively.

<u>Delta Clearwater River</u>

The estimated relative abundance of grayling in the Delta Clearwater River was the same as electrofishing CPUE estimates made in 1985 (Holmes et al. 1986) and 1986 (Clark and Ridder 1987b). The bootstrap mean CPUE in 1987 was 3.0 grayling per electrofishing run for the downstream section and 6.7 grayling per run for the upstream section, with a combined CPUE of 9.7 grayling per run (Table 11). The 1986 CPUE index of 7.3 and 1987 index of 9.7 grayling per run were not significantly different from one another, but both of these estimates were considerably lower than the 14 year average (1974 through 1987) of 52.1 grayling per electrofishing run. Electrofishing CPUE in the upstream section was approximately twice as high as in 1986, although inter-year variability in CPUE is quite high in this section. There was no significant change in electrofishing CPUE in the downstream section between 1986 and 1987.

Low CPUE in the downstream section of the Delta Clearwater River was unexpected. It was presumed that enhancement efforts begun in 1983 (Ridder 1984) would have increased the abundance of grayling in this area of the river in 1987. Electrofishing CPUE should have shown a proportional increase as a result of these enhancement efforts. The absence of a detectable increase in grayling abundance, as measured by electrofishing CPUE, does not absolutely prove that enhancement efforts have failed, but it may prove that the relative abundance index is not sensitive to small changes in absolute abundance (Ridder 1983). Of the 16 grayling captured in the downstream section, seven were of hatchery origin (see Skaugstad 1988).

Ninety-one grayling were sampled from the Delta Clearwater River for estimation of age and size composition. July (59 grayling) and September (32 grayling) samples were combined because of low numbers of grayling captured.

Table 10. Estimates of sampled and adjusted[1] proportional contribution of each age class, sampled mean fork length (mm) at age, and standard errors for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the Salcha River stock, 1 to 10 June 1987.

	Sampled:		Adjusted:		Fork Length:	
Age	n[2]	p[3]	p[4]	SE[5]	Mean[6]	SE[7]
2	2	0.004	0.006	0.004	138	5
3	35	0.067	0.095	0.031	203	6
4	205	0.394	0.503	0.073	241	2
5	120	0.231	0.200	0.051	275	3
6	80	0.155	0.106	0.028	311	4
7	56	0.108	0.066	0.020	339	4
8	15	0.029	0.017	0.007	356	9
9	4	0.008	0.004	0.003	371	15
10	2	0.004	0.002	0.002	444	16
Total	519	1.000	1.000		274	2

[1] Age composition is adjusted to compensate for bias in the electrofishing sample. Adjustment factors are taken from the Upper Chena abundance estimate.

[2] n = sample size.

[3] p = proportion of sampled grayling.

[4] p = adjusted proportion of grayling in stock.

[5] SE = standard error of the adjusted proportion.

[6] Mean = average fork length of all sampled grayling for a particular age (includes grayling < 150 mm FL).

[7] SE = standard error of the mean fork length.

Table 11. Catch rate (CPUE)[1] statistics for Arctic grayling from each of five electrofishing runs through two 4.8-kilometer sections of the Delta Clearwater River, 6 to 16 July 1987.

		Catch Rate[2]		
Date	Run	KM 8.0-11.2	KM 24.0-27.2	Both
6 July	1	4	6	10
8 July	2	3	4	7
9 July	3	3	10	13
14 July	4	2	7	9
16 July	5	4	5	9
	mean	3.0	6.7	9.7
	variance	0.1	1.0	0.9
	SE	0.3	1.0	0.9
	95% C.I.	2.4 - 3.5	6.4 - 7.7	8.9 - 10.7

[1] CPUE is the number of grayling caught in one electrofishing run through a section.

[2] Summary statistics developed from bootstrap methods (Efron 1981 and 1982).

All but one grayling sampled in September were captured along a section of river extending from Mile One Slough to a point 0.8 km downstream. Most grayling were found in the muddy water interface below the mouth of Mile One Slough. The September sample contained no grayling older than age 7. Age 4 grayling were the predominant age class, representing 25% of the electrofishing sample from the Delta Clearwater River (Table 12). This year class (born in 1983) showed strong recruitment in drainage-wide samples taken in 1986 (as age 3; Clark and Ridder 1987b) and in 1987 (as age 4). This is the first year since 1978 that this age class has predominated in the Delta Clearwater River electrofishing sample (Peckham and Ridder 1979). The predominance of age 4 grayling in the sample is reflected in relative stock density indices. Seventy-one percent of the sample were of quality size and larger (Table 13).

Two tagged fish were recovered during electrofishing for age-length samples and estimation of relative abundance. One of these recaptured grayling was initially tagged at Caribou Creek in June 1987 and the other was initially tagged during egg-take operations at the lower Goodpaster River in May 1985.

An additional 90 age-length samples were collected during seining on 1 September. The seine sample came exclusively from a broad riffle area 1,000 m above a State boat launch at river km 13.2. Seine hauls made at three additional areas downstream of the boat launch caught no grayling. The sample contained a large proportion of juvenile grayling of hatchery origin. Sixty-nine percent of grayling sampled in September were from the enhancement program as described by Skaugstad and Ridder (1987) and Skaugstad (1988). Age 1 grayling were most numerous in the sample and no fish greater than age 5 were caught (Table 14).

Richardson Clearwater River

The estimate of absolute abundance in sections 1 and 2 combined was 1,407 grayling (≥ 250 mm FL) or 147 grayling per km (Table 15). Abundance of grayling in section 3 was 1,368 fish or 428 grayling per km. Combining these two section estimates, there were an estimated 2,775 grayling in the lower 12.8 km of the Richardson Clearwater River (SE = 572 grayling; CV = 20.6%). While this estimate is 196% greater than the 1986 estimate, the imprecision of these estimates results in a nonsignificant difference.

The estimated CPUE (number of grayling caught in one electrofishing run through a section) for the three sections combined was 110.0 grayling per run. Electrofishing CPUE ranged from 24.0 to 58.5 grayling per run for the individual sections (Table 16). The combined CPUE represented a 275% increase over the 1986 estimate of 40.3 grayling per run, although the 1986 estimate was based on five electrofishing runs. Bootstrap variance calculated from three data points may be seriously biased with respect to the variance of all possible CPUE. The fact that combined CPUE for run four was 60 grayling and the lower 95% confidence limit was 73% (44 grayling) greater than this value tends to substantiate the use of caution when comparing the 1987 CPUE data with the 1986 data (Table 16).

Table 12. Estimates of the sampled proportional contribution of each age class, mean fork length (mm) at age, and standard errors for Arctic grayling captured by electrofishing the Delta Clearwater River, 6 to 16 July, and 1 September 1987.

	Age Composition:			Fork Length(mm):	
Age	n[1]	p[2]	SE[3]	Mean	SE[4]
2	15	0.172	0.040	202	6
3	1	0.011	0.011	205	---
4	22	0.253	0.047	274	4
5	9	0.103	0.033	301	10
6	10	0.115	0.034	327	5
7	11	0.126	0.036	340	9
8	8	0.092	0.031	385	8
9	7	0.080	0.029	378	9
10	1	0.011	0.011	385	---
11	2	0.023	0.016	400	22
12	1	0.011	0.011	408	---
Total	87	1.000		303	7

[1] n = sample size.

[2] p = proportion of sampled grayling.

[3] SE = standard error of the sampled proportion.

[4] SE = standard error of the mean fork length.

Table 13. Summary of sampled and adjusted Relative Stock Density (RSD) indices for grayling (≥ 150 mm FL) sampled in the Delta and Richardson Clearwater Rivers, July 1987.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
<u>Delta Clearwater</u>					
Number sampled	26	34	31	0	0
Sampled RSD[2]	0.286	0.374	0.341	---	---
Standard Error[3]	0.047	0.051	0.050	---	---
<u>Richardson Clearwater</u>					
Number sampled	95	213	205	0	0
Sampled RSD	0.185	0.415	0.400	---	---
Adjusted RSD[4]	0.122	0.583	0.295	---	---
Standard Error[5]	0.020	0.047	0.054	---	---

[1] Minimum lengths (FL) for RSD categories are (Gablehouse 1984):
Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm

[2] RSD calculated directly from the number sampled.

[3] Standard error of the sampled RSD.

[4] RSD indices for grayling ≥ 250 mm FL adjusted for bias due to length selectivity of the electrofishing boat.

[5] Standard error of adjusted RSD calculated by bootstrap methods.

Table 14. Estimates of the sampled proportional contribution of each age class, mean fork length (mm) at age, and standard errors for wild (W) and stocked (S) Arctic grayling captured by seine at river km 13.6, Delta Clearwater River, 1 September 1987.

		Age composition:			Fork length (mm):	
Age	Source	n[1]	p[2]	SE[3]	Mean	SE[4]
1	W	5	0.056	0.024	152	4
	S	40	0.444	0.052	173	2
	Subtotal	45	0.500	0.053	171	2
2	W	17	0.189	0.041	201	4
	S	22	0.244	0.045	219	3
	Subtotal	39	0.433	0.052	211	3
3	W	5	0.056	0.024	220	11
	S	0	0.000	---	---	---
	Subtotal	5	0.056	0.024	220	11
4	W	1	0.011	0.011	260	---
	S	0	0.000	---	---	---
	Subtotal	1	0.011	0.011	260	---
Total		90	1.000		192	3

[1] n = sample size.

[2] p = proportion of sample.

[3] SE = standard error of the sampled proportion.

[4] mean = mean fork length at age

Table 15. Capture probabilities and estimated abundance in two length categories used for population estimation of grayling (≥ 250 mm FL) in Sections 1 and 2, Section 3, and all sections combined of the Richardson Clearwater River, 7 July to 3 August 1987.

Length Category	Marks	Catch	Recaps	CP[1]	SE[CP][2]	$\hat{N}$[3]	$\hat{SE[N]}$[4]
Section 1 and 2							
250-349	110	180	9	0.090	0.074	1,191	333
≥ 350	22	50	4	0.184	0.071	216	93
Total	132	230	13	---	---	1,407	346
Section 3							
250-349	105	121	4	0.056	0.021	1,002	438
≥ 350	111	137	12	0.139	0.038	366	125
Total	216	258	16	---	---	1,368	455
River Total	348	488	29	---	---	2,775	572

[1] CP is the probability of capture determined from bootstrap methods.

[2] SE[CP] is the standard error of CP determined from bootstrap methods.

[3] N is the estimated abundance, determined from bootstrap methods.

[4] SE[N] is the bootstrap standard error of N.

Table 16. Catch rate (CPUE)[1] statistics for Arctic grayling from each of three electrofishing runs through three sections of the Richardson Clearwater River, 10 to 15 July 1987.

		Catch Rate[2]			
Date	Run[3]	Section 1	Section 2	Section 3	Total
10 July	2	16	32	65	113
13 July	3	39	16	52	107
15 July	4	19	18	23	60
mean		27.5	24.0	58.5	110.0
variance		46.0	22.3	14.7	3.1
SE		6.8	4.7	3.8	1.8
95% C.I		14.2-40.8	14.8-33.2	51.0-66.0	103.9-116.1

[1] CPUE is the number of grayling caught in one electrofishing run through a section.

[2] Summary statistics developed from bootstrap methods (Efron 1981 and 1982).

[3] Run 1 was excluded because of new electrofishing configuration; runs 5 and 6 were excluded because of a different electrofishing current; runs 2 through 4 are with AC current and conduit electrodes.

A total of 14.3 sampling hours were expended to conduct the six electrofishing runs. Five hundred forty-five grayling were caught, for a catch rate of 38 grayling per electrofishing hour.

Four hundred seventy-two grayling were collected to estimate age and size composition in the Richardson Clearwater River. Ages 5 and 7 were most numerous in the electrofishing sample, comprising 17% and 18% of the sample respectively (Table 17). When adjusted for length selectivity of the electrofishing gear, these same age classes were also predominant, with each age class comprising approximately 24% of all grayling (Table 17). RSD indices of grayling in the Richardson Clearwater River reflected the high abundance of older grayling, with 88% quality size and larger grayling in the population (Table 13).

During sampling in the Richardson Clearwater River, 75 tagged grayling were recovered. Of those grayling recovered at the Richardson Clearwater River, 54 were initially marked (tag or finclip) at Caribou Creek weir; 12 of which were tagged in June 1987. Eighteen of the recovered grayling were initially tagged at the mouth of Shaw Creek in April 1987. Three of the recovered grayling were initially tagged during an egg take on the Goodpaster River in May 1987. Long term tag loss was estimated as 54.5% (6 lost out of 11 examined; SE = 15.7% lost tags; CV = 28.8%) for grayling initially tagged at Caribou Creek weir in June 1982. The estimated average tag loss per year over the 5 year period was 10.9% (SE = 3.1% lost per year; CV = 28.8%).

Goodpaster River

Electrofishing sampling was conducted for 5 days in the downstream section and for 4 days in the upstream section during 4 to 10 August. The first four marking events in each section occurred on consecutive days. A total of 21.2 hours were spent electrofishing both sections. Four hundred sixty grayling were captured for an estimated CPUE of 21.7 fish per hour, while CPUE in 1986 was 47 grayling per hour (Clark and Ridder 1987). AC electrofishing gear captured grayling at a rate of 25.9 fish per hour, while DC electrofishing gear captured 17.1 fish per hour. Water level was extremely low and water clarity was high during the experiment.

No significant differences in capture probabilities were found among length categories from either section, so neither estimate was stratified ($\chi^2 = 0.24$, df = 1, P > 0.50 and $\chi^2 = 0.06$, df = 1, P > 0.90, for downstream and upstream sections, respectively). The abundance of grayling greater than 149 mm FL in the downstream section was estimated as 901 grayling (SE = 251 grayling, CV = 27.8%) or 188 grayling per km. In the upstream section, the estimate was 639 grayling (SE = 133 grayling, CV = 20.8%) or 133 grayling per kilometer. Both estimates are approximately 50% of the 1986 abundance estimates.

Program CAPTURE was employed to detect departures from assumptions necessary to multiple-sample designs. Program CAPTURE chose a model that allowed for behavioral and temporal changes in capture probabilities, but no closed form estimator was available for this model (see Otis et al. 1978). The results from program CAPTURE indicate that some of the assumptions of abundance

Table 17. Estimates of sampled and adjusted[1] proportional contribution of each age class, sampled mean fork length (mm) at age, and standard errors for Arctic grayling captured by electrofishing the Richardson Clearwater River, 7 July to 3 August 1987.

	Sampled:		Adjusted:		Fork Length(mm):	
Age	n[2]	p[3]	p[4]	SE[5]	Mean[6]	SE[7]
1	1	0.002	0.000	---	115	---
2	0	0.000	0.000	---	---	---
3	10	0.021	0.003	0.003	224	6
4	69	0.146	0.083	0.014	246	2
5	81	0.172	0.237	0.024	283	2
6	57	0.121	0.179	0.020	308	3
7	87	0.184	0.235	0.023	330	3
8	55	0.117	0.102	0.015	351	3
9	49	0.104	0.074	0.019	372	3
10	38	0.081	0.054	0.015	397	3
11	19	0.040	0.023	0.009	404	5
12	6	0.013	0.008	0.004	417	9
Total	472	1.000	1.000		322	3

[1] Age composition is adjusted to compensate for length bias in the electrofishing sample.

[2] n = sample size.

[3] p = proportion of sampled grayling.

[4] p = adjusted proportion of grayling (≥ 250 mm) in stock.

[5] SE = standard error of the adjusted proportion.

[6] Mean = average fork length of all sampled grayling of a particular age (includes grayling < 150 mm FL).

[7] SE = standard error of the mean fork length.

estimation are not being met. Therefore, any estimate of abundance must be interpreted with caution. The fact that the modified Schnabel estimate is presented here does not imply that it is the best estimator in this case. Possible causes for the violation of assumptions were high water clarity and low water level (avoidance of gear), daily fishing of two capture gears in the same area (trap shyness), and grayling leaving the area (closure violation), and most likely, a combination of these effects.

No significant differences in age composition were found among the two river sections ($\chi^2 = 4.58$, $df = 5$, $P > 0.25$), therefore the age data from each section were combined. A total of 358 grayling was sampled for age and length. Age 4 grayling comprised 46% of the sample, whereas the next most prevalent age represented only 15% (Table 18). The continued strength of the 1983 year class, in conjunction with poor recruitment to the age 3 component of the stock, increased the mean length of the sample from 211 mm FL in 1986 to 233 mm FL in 1987 (Table 18). Age 5 grayling represented only 3% of the stock, although age samples from Caribou Creek, Richardson Clearwater River, and the Salcha River have strong age 5 components.

As indicated by incremental RSD indices, grayling of stock size were the most prevalent size group in the lower Goodpaster River. Stock size fish comprised 81% of the combined samples from the two sections, while quality size and larger fish made up only 19% (Table 19).

Seventeen tagged grayling were recovered during sampling of the Goodpaster River. Of the tagged grayling that were recovered, four were tagged at the Goodpaster River during grayling egg-take operations. Three of the four recovered grayling were tagged during May 1986 and one was tagged in May 1987. The remaining 13 grayling were stocked as fingerlings in the Delta Clearwater River as part of enhancement evaluations (see Skaugstad 1988).

Caribou Creek

The weir trap at Caribou Creek was fished continuously from 3 to 11 June. For the second consecutive year, water levels did not breach the weir trap. Water level fell steadily from 66 cm on 3 June to 23 cm on 11 June. Water temperatures rose steadily from 0.8°C on 1 June to 10.5°C on 11 June. A total of 932 grayling was captured, of which 315 grayling were determined to be sexually mature. The sex ratio was 125 males to 190 females (0.66:1). Of the 780 grayling greater than 199 mm FL, 698 were tagged and 82 were tag recoveries from previous years. These recaptured fish included 77 grayling tagged at Caribou Creek in previous years, one grayling tagged at Clear Creek in 1984, and four grayling tagged 1.5 months earlier at the mouth of Shaw Creek.

Of the 443 grayling sampled for age, 46% were ages 4 and 5 (Table 20). These same cohorts comprised a similar percentage as age 3 and age 4 grayling in 1986 (Clark and Ridder 1987b). Age 7 fish predominated in the adult male and female samples taken at Caribou Creek in 1987 (Table 21). Quality size and larger grayling comprised 42% of the Caribou Creek sample (Tables 22 and 23).

Table 18. Estimates of the sampled proportional contribution of each age class, sampled mean fork length (mm) at age, and standard errors for Arctic grayling (≥ 150 mm FL) captured by electrofishing two 4.8-kilometer sections in the lower Goodpaster River, 3 to 10 August 1987.

	Age Composition:			Fork Length(mm):	
Age	n[1]	p[2]	SE[3]	Mean	SE[4]
1	6	0.017	0.007	166	7
2	55	0.154	0.019	183	2
3	51	0.142	0.018	206	2
4	165	0.461	0.026	233	1
5	9	0.025	0.008	264	5
6	22	0.061	0.013	276	3
7	32	0.089	0.015	288	3
8	12	0.034	0.010	296	5
9	5	0.014	0.006	341	15
10	1	0.003	0.003	311	---
Total	358	1.000		233	2

[1] n = sample size.

[2] p = proportion of sampled grayling.

[3] SE = standard error of the sampled proportion.

[4] SE = standard error of the mean fork length.

Table 19. Summary of Relative Stock Density (RSD) indices for grayling ($\geq$ 150 mm FL) sampled in two 4.8-km sections in the lower Goodpaster River, 3 to 10 August 1987.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
<u>4.8 to 9.6 km</u>					
Number sampled	137	33	1	0	0
Sampled RSD[2]	0.801	0.193	0.006	---	---
Standard Error[3]	0.031	0.030	0.006	---	---
<u>24.0 to 28.8 km</u>					
Number sampled	153	33	1	0	0
Sampled RSD	0.818	0.176	0.005	---	---
Standard Error	0.028	0.028	0.005	---	---
Total	290	66	2	0	0
Sampled RSD	0.810	0.184	0.006	---	---
Standard Error	0.021	0.020	0.004	---	---

1 Minimum lengths (FL) for RSD categories are (Gablehouse 1984):
- Stock - 150 mm
- Quality - 270 mm
- Preferred - 340 mm
- Memorable - 450 mm
- Trophy - 560 mm

2 RSD calculated directly from the number sampled.

3 Standard error of sampled RSD.

Table 20. Estimates of the sampled proportional contribution of each age class, sampled mean fork length (mm) at age, and standard errors for Arctic grayling captured by weir trap at Caribou Creek, 3 to 11 June 1987.

	Age Composition:			Fork Length(mm):	
Age	n[1]	p[2]	SE[3]	Mean	SE[4]
1	6	0.014	0.005	88	2
2	36	0.081	0.013	138	2
3	9	0.020	0.007	182	8
4	100	0.226	0.020	226	2
5	102	0.230	0.020	267	2
6	46	0.104	0.014	298	4
7	80	0.181	0.018	321	3
8	29	0.065	0.012	347	5
9	21	0.047	0.010	364	5
10	9	0.020	0.007	365	11
11	2	0.005	0.003	369	2
12	3	0.007	0.004	400	6
Total	443	1.000		269	3

[1] n = sample size.

[2] p = proportion of sampled grayling.

[3] SE = standard error of the sampled proportion.

[4] SE = standard error of the mean fork length.

Table 21. Estimates of the sampled proportional contribution of each age class and standard error for adult male and female Arctic grayling, Caribou Creek, 3 to 11 June 1987.

	Males:			Females:		
Age	n[1]	p[2]	SE[3]	n	p	SE
4	1	0.012	0.012	3	0.022	0.013
5	12	0.148	0.039	27	0.200	0.034
6	14	0.173	0.042	19	0.141	0.030
7	24	0.296	0.051	53	0.393	0.042
8	14	0.173	0.042	15	0.111	0.027
9	9	0.111	0.035	11	0.081	0.024
10	4	0.049	0.024	5	0.037	0.016
11	1	0.012	0.012	1	0.007	0.007
12	2	0.025	0.017	1	0.007	0.007
Total	81	1.000		135	1.000	

[1] n = sample size.

[2] p = proportion of sampled grayling.

[3] SE = standard error of the sampled proportion.

Table 22. Estimates of the sampled mean fork length (mm) at age and standard errors for adult male and female Arctic grayling, Caribou Creek, 3 to 11 June 1987.

	Males:			Females:		
Age	n[1]	Mean	SE[2]	n	Mean	SE
4	1	281	---	3	244	7
5	12	296	5	27	275	4
6	14	312	6	19	301	5
7	24	341	4	53	313	3
8	14	358	5	15	336	5
9	9	359	6	11	371	5
10	4	362	14	5	367	12
11	1	367	---	1	370	---
12	2	405	8	1	392	---
Total	81	337	4	135	313	3

1 n = sample size.

2 SE = standard error of the mean fork length.

Table 23. Summary of Relative Stock Density (RSD) indices for grayling (≥ 150 mm FL) and for adults sampled in April in the Tanana River at Shaw Creek and in June at Caribou Creek, 1987.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
<u>Tanana</u>					
Number sampled	16	79	170	0	0
Sampled RSD[2]	0.060	0.298	0.642	---	---
Standard Error[3]	0.015	0.028	0.029	---	---
<u>Caribou</u>					
Number sampled	477	256	87	0	0
Sampled RSD	0.582	0.312	0.106	---	---
Standard Error	0.017	0.016	0.011	---	---
<u>Tanana-Adults</u>					
Number sampled	1	64	170	0	0
Sampled RSD	0.004	0.272	0.723	---	---
Standard Error	0.004	0.029	0.029	---	---
<u>Caribou-Adults</u>					
Number sampled	27	201	87	0	0
Sampled RSD	0.086	0.638	0.276	---	---
Standard Error	0.016	0.027	0.025	---	---

[1] Minimum lengths (FL) for RSD categories are (Gablehouse 1984):
Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm

[2] RSD calculated directly from the number sampled.

[3] Standard error of sampled RSD.

Shaw Creek

Six days were spent electrofishing the Tanana River approximately 1.6 km above and below the mouth of Shaw Creek during 15 to 23 April. Rising water levels and increasing turbidity made sampling after 23 April unproductive. Grayling were consistently found in only two small areas. One area was located 0.8 km above the mouth in a backwater slough approximately 50 m wide, 300 m long, and 3 m deep. The other area was 0.8 km below the mouth in the main channel of the Tanana River. Grayling were holding in a 100 m long and 1 m deep section of water adjacent to the main current. A few grayling were also captured along the shoreline immediately above and below the mouth of Shaw Creek and on the shore opposite the creek mouth.

1987 Abundance Estimate:

A total of 288 grayling was captured during approximately 20 hours of electrofishing, 23 of which were recaptured during sampling. Of the 265 individual grayling captured, 39 were recoveries of fish tagged in past years. Thirty-seven fish were initially captured and tagged at Caribou Creek in previous years, one fish was tagged in September 1979 at the mouth of Caribou Creek, and one fish was tagged at Clear Creek in July 1984.

The estimated abundance of grayling in Shaw Creek in 1987 was 10,520 grayling (Marks = 239, Catch = 262, Recaps = 5, SE = 3,881 grayling, CV = 36.9%). This estimate applied to grayling greater than 289 mm FL only. Ninety percent of the sample marked were greater than 289 mm FL, while only 35% of the recapture sample were greater than 289 mm FL. The small number of recaptures at the Caribou Creek weir prevented stratification or adjustment of the estimate by length category despite significant differences in length frequencies between the marking and recapture samples (χ^2 = 87.8, df = 6, P < 0.001). To correct for the larger proportion of small fish captured at Caribou Creek, a minimum length of 290 mm FL was chosen. This choice was based on the minimum size of the recaptures.

The assumption of a closed population during the experiment was violated, as evidenced by the recovery of marked fish in the Goodpaster River during egg-take operations on 12 May and in the Salcha River during sampling on 9 June. The marking run was assumed to have been conducted after the pre-spawning migration from overwintering areas and thus assumed to be operating on a closed population awaiting break-up of and access to spawning areas in Shaw Creek. Loss of marks due to emigration during the experiment would result in an over estimate of abundance.

1986 Abundance Estimate:

A Jolly-Seber estimate of grayling abundance in Shaw Creek in 1986 was calculated from recapture data collected during the marking run at the mouth of Shaw Creek in 1987. The 1986 estimate of abundance was 78,596 grayling (SE = 50,021 grayling, CV = 63.6%). This estimate is most likely biased high because the estimate of survival from marking in 1985 to 1986 was greater than 1.00 (Table 24). The paucity of tag recoveries in the 1986 creel census sample and subsequent increase in recoveries in the 1987 electrofishing sample

Table 24. Summary of estimated parameters for the generalized Jolly-Seber model[1] of grayling abundance, survival, and recruitment in Shaw Creek, 1980 to 1986.

Year	Parameter	Estimate	SE	CV	z^2	P^3
1980	Abundance	---	---	---	---	---
	Survival	0.89	0.18	20.2	4.95	0.000
	Recruitment	---	---	---	---	---
1981	Abundance	27,509	7,708	28.0	3.57	0.000
	Survival	0.87	0.18	20.6	4.85	0.000
	Recruitment	-4,171	6,428	154.1	-0.65	0.258
1982	Abundance	20,297	4,863	23.9	4.18	0.000
	Survival	0.41	0.13	31.7	3.15	0.001
	Recruitment	3,194	2,717	85.1	1.17	0.121
1983	Abundance	12,267	3,010	24.5	4.08	0.000
	Survival	0.56	0.25	44.6	2.24	0.012
	Recruitment	6,841	2,498	36.5	2.74	0.003
1984	Abundance	13,994	5,737	41.0	2.44	0.007
	Survival	0.99	0.58	58.6	1.71	0.044
	Recruitment	1,231	3,034	246.5	0.41	0.341
1985	Abundance	14,812	7,370	49.7	2.01	0.053
	Survival	1.16	0.58	50.0	2.00	0.022
	Recruitment	61,438	38,928	63.4	1.58	0.057
1986	Abundance	78,596	50,021	63.6	1.57	0.058
	Survival	---	---	---	---	---
	Recruitment	---	---	---	---	---

[1] Actual model used is the modified Jolly-Seber model of Seber (1982).

[2] z statistic is for the single tailed hypothesis H_0: The estimated parameter is not different from 0 (large samples and normality assumed).

[3] Approximate probability that the estimated parameter is not different from 0.

was the primary reason for biased estimates of survival and recruitment in 1985 and a biased estimate of abundance in 1986 (see Clark and Ridder 1987a). The 1986 estimate of abundance may stabilize as more recoveries of grayling tagged in 1986 are made in the future. Another possible cause for bias in 1985 and 1986 estimates was that emigration may not have been permanent. The Jolly-Seber model, and most other models of open populations, require that emigration not exist, or if it exists it must be permanent, so that emigrants can be considered "dead" (Seber 1982). The recovery of tags in the Salcha and Goodpaster Rivers indicate that emigration does occur, but does not indicate that emigration is permanent. Ridder (1984, 1985) found that grayling tagged while departing Caribou Creek may not utilize Caribou Creek for spawning every year after tagging. If this hypothesis is correct, emigration may only be partial, so that grayling using Caribou Creek for spawning one year may use another system the next year. To ascertain the validity of this estimation experiment a more complete analysis of grayling migration patterns in the Tanana Drainage is needed.

Age and Size Composition in 1987:

Estimates of grayling age composition in Shaw Creek indicated that grayling age 7 and older comprised 81% of the sample (Table 25). Age 7 and age 8 grayling predominated in the age-length sample at 24% and 20%, respectively. Ninety-four per cent of the sample was quality size or larger, with 64% of preferred size (Table 23).

Of the 265 grayling captured at the mouth of Shaw Creek, 235 were determined to be of adult size. Seventy-two percent of adult grayling were of preferred size (Table 23). Of these preferred size grayling, 167 were males and 68 were females (2.45:1). This ratio was significantly different than the 0.66:1 ratio estimated 5 weeks later at the Caribou Creek weir.

Fielding Lake

Fielding Lake was first visited on 21 May to survey the outlet stream of the lake for possible spawning activity. No fish were sighted during the visual survey of an area from the lake outlet to a point 300 m downstream. Water temperature was 3.5°C. The lake was ice-covered except for a large area adjacent to the outlet. The inlet streams to Fielding Lake were not surveyed at this time.

Abundance Estimate:

Marking of grayling for abundance estimation (phase one) occurred during 15 to 21 June. Water temperatures ranged from 5.0°C at the lake surface and 4.0°C in the inlet streams on 15 June to 10.0°C at the lake surface, 9.0°C in Two-Bit Creek, and 6.5°C in Caribou Bay Creek on 20 June. A total of 679 grayling was captured by three gear types in the lake, inlet streams, and outlet stream (Table 26). Four hundred sixty-nine grayling ($\geq$ 200 mm FL) were tagged and marked with a clip of the upper lobe of the caudal fin.

Recapture efforts (phase two) were conducted from 20 to 25 August. A total of 1,369 grayling was captured, of which 784 were greater than 199 mm FL

Table 25. Estimates of the sampled proportional contribution of each age class, sampled mean fork length (mm) at age, and standard errors for Arctic grayling captured by electrofishing the Tanana River 1 km above and below the mouth of Shaw Creek, 15 to 23 April 1987.

	Age Composition:			Fork Length(mm):	
Age	n[1]	p[2]	SE[3]	Mean	SE[4]
3	1	0.004	0.004	200	---
4	10	0.045	0.014	229	6
5	10	0.045	0.014	281	10
6	21	0.094	0.019	307	5
7	54	0.241	0.029	330	3
8	45	0.201	0.027	360	3
9	37	0.165	0.025	372	3
10	29	0.129	0.022	383	4
11	13	0.058	0.016	406	4
12	4	0.018	0.009	393	6
Total	224	1.000		346	3

[1] n = sample size.

[2] p = proportion of sampled grayling.

[3] SE = standard error of the sampled proportion.

[4] SE = standard error of the mean fork length.

Table 26. Summary of marking and recapture samples from Fielding Lake, 1987.

Phase	Date	Gear Type	Number Captured: < 200 mm	Number Captured: ≥ 200 mm
1	15 to 21 June	Electrofishing	79	222
		Fyke Weirs	114	222
		Seining	17	25
			210	469
2	20 to 25 Aug	Electrofishing	79	610
		Seining	506	174
			585	784

(Table 26). Fifteen grayling marked during phase one of the abundance estimate were recaptured. A Kolmogorov-Smirnov two-sample test revealed no significant bias due to length selectivity in the phase two sample (DN = 0.206, n_1 = 469, n_2 = 15, P > 0.99).

Significant recruitment of grayling into the unmarked population (fish ≥ 200 mm FL) occurred during the interval between phase one and phase two of the estimation experiment. The smallest size grayling recovered from phase one was 243 mm FL, while 298 grayling from 200 to 243 mm FL were examined for marks (Table 27). The estimated number of unmarked grayling in the phase two sample that were also ≥ 200 mm FL during phase one sampling was 60 grayling. To eliminate the bias due to recruitment, 237 unmarked grayling between 200 and 243 mm FL were culled from the phase two data. The remaining number of grayling examined in phase two was 547 fish (784 grayling - 237 recruits = 547 grayling). The modified Petersen estimate of grayling in Fielding Lake was 16,097 grayling (SE = 3,780 grayling, CV = 23.4%) in June.

On the night of 6 October a pulsed-DC electrofishing boat was used to capture additional grayling for examination for tagged fish, length samples, and to document seasonal movements of grayling by size class. A total of 235 grayling was captured along the southern shore of the lake and 135 grayling along the northern shore of the lake. Three grayling marked in June were recaptured during October sampling. These samples were not included in the grayling abundance estimate calculations.

Age and Size Composition:

Age 7 was the dominant age class of grayling captured in the lake and inlet creeks during June; age 4 was the dominant age sampled in the outlet creek (Tables 28 and 29). The overall age composition of grayling was weighted towards larger fish. Thirty-one percent of the estimated grayling abundance was age 7 (Table 30). Age 6 grayling (1981 year class) comprised a much larger part of the population (20%) than was estimated in 1986 (6%). The age 3 component represented 25% of the population in 1986 and only 3% of the population in 1987. The variable age class composition indicates that Fielding Lake grayling may experience recruitment patterns similar to those found in riverine stocks of the Tanana Drainage.

A summary of RSD indices for all the samples mentioned above show strong seasonal movements and availability among large and small grayling (Table 31). Larger grayling appear to move away from littoral areas of the lake and from the outlet creek as winter approaches. Quality size and larger grayling comprised 45% of the June and August lake samples, but only 5% of the October sample. Similarly, quality size and larger grayling comprised 31% of the outlet sample in June and only 6% in August.

Discussion:

The estimate of grayling abundance in June 1987 was 2.4 times larger than the 1986 estimate. While the 1987 estimate in June is biologically plausible, the relation between 1986 and 1987 abundance estimates reveals discrepancies in one or both of these estimates. The June 1986 estimate of grayling abundance

Table 27. Nonparametric recruitment tests[1] performed on the Fielding Lake mark-recapture data, 15 to 21 June and 20 to 25 August 1987 (the Bonferroni confidence level for 15 comparisons is $\alpha = 0.0033$).

Length Category	Marked	Unmarked	Probability of greater unmarked	Significant?
200-243	1	297	0.0006	YES
244-248	1	34	0.3417	NO
249-250	1	11	0.7117	NO
251-251	1	5	0.8645	NO
252-255	1	32	0.4081	NO
256-259	1	26	0.4889	NO
260-317	1	186	0.0011	YES
318-331	1	22	0.3146	NO
332-338	1	14	0.4809	NO
339-359	1	56	0.0299	NO
360-364	1	19	0.2051	NO
365-378	1	33	0.0143	NO
379-381	1	9	0.1033	NO
382-382	1	0	1.0000	NO
≥ 383	1	6	---	---
Average Unmarked		60		

[1] Recruitment test developed by Robson and Flick (1965).

Table 28. Estimates of the proportional contribution of each age class and standard error for Arctic grayling captured by electrofishing in Fielding Lake and by fyke weir in Two Bit Creek, 16 to 20 June 1987.

	Fielding Lake:			Two Bit Creek:		
Age	n[1]	p[2]	SE[3]	n	p	SE
1	0	---	---	21	0.025	0.009
2	12	0.041	0.012	23	0.080	0.016
3	68	0.234	0.025	62	0.215	0.024
4	90	0.309	0.027	20	0.069	0.015
5	25	0.086	0.016	10	0.035	0.011
6	22	0.076	0.015	63	0.219	0.024
7	55	0.189	0.023	73	0.253	0.026
8	16	0.055	0.013	14	0.049	0.013
9	3	0.010	0.006	2	0.007	0.005
Total	291	1.000		288	1.000	

[1] n = sample size.

[2] p = proportion of sampled grayling.

[3] SE = standard error of the sampled proportion.

Table 29. Estimates of the proportional contribution of each age class and standard error for Arctic grayling captured by seine in Fielding Lake outlet and by fyke weir in Caribou Bay Creek, 17 to 19 June 1987.

	Outlet:			Caribou Bay Creek:		
Age	n[1]	p[2]	SE[3]	n	p	SE
2	1	0.024	0.024	1	0.026	0.025
3	12	0.286	0.070	5	0.128	0.054
4	17	0.405	0.076	2	0.051	0.035
5	8	0.190	0.061	9	0.231	0.067
6	3	0.071	0.040	2	0.051	0.035
7	0	---	---	15	0.385	0.078
8	0	---	---	5	0.128	0.054
9	1	0.024	0.024	0	---	---
Total	42	1.000		39	1.000	

[1] n = sample size.

[2] p = proportion of sampled grayling.

[3] SE = standard error of the sampled proportion.

Table 30. Estimates of the proportional contribution of each age class and standard error for Arctic grayling (≥ 200 mm FL) in the population and the mean fork length (mm) at age for all grayling captured by three gear types at Fielding Lake, 16 to 21 June 1987.

	Age Composition:			Fork Length (mm):		
Age	n[1]	p[2]	SE[3]	n[4]	Mean	SE[5]
1	0	---	---	21	80	3
2	0	---	---	37	121	2
3	16	0.035	0.009	147	169	2
4	114	0.250	0.020	129	230	2
5	52	0.114	0.015	52	291	4
6	90	0.197	0.019	90	336	2
7	143	0.314	0.022	143	357	1
8	35	0.077	0.012	35	377	3
9	6	0.013	0.005	6	387	4
Total	456	1.000		660	264	4

[1] n = number sampled that are greater than 199 mm FL.

[2] p = proportion of sampled grayling.

[3] SE = standard error of the proportion.

[4] n = number sampled from all gear types.

[5] SE = standard error of the mean fork.

Table 31. Summary of Relative Stock Density (RSD) indices for grayling ($\geq$ 150 mm FL) sampled in four areas of Fielding Lake in June, August, and October 1987.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
Outlet-June					
Number sampled	27	11	1	0	0
Sampled RSD[2]	0.692	0.282	0.026	---	---
Standard Error[3]	0.071	0.069	0.024	---	---
Outlet-August					
Number sampled	363	20	4	0	0
RSD	0.938	0.052	0.010	---	---
Standard Error	0.012	0.011	0.005	---	---
Tributaries-June[4]					
Number sampled	71	61	140	0	0
RSD	0.261	0.224	0.515	---	---
Standard Error	0.027	0.025	0.030	---	---
Lake-June					
Number sampled	156	48	78	0	0
RSD	0.553	0.170	0.277	---	---
Standard Error	0.030	0.022	0.027	---	---
Lake-August					
Number sampled	372	165	141	0	0
RSD	0.549	0.243	0.208	---	---
Standard Error	0.019	0.016	0.016	---	---
Lake-October					
Number sampled	321	15	2	0	0
RSD	0.950	0.044	0.006	---	---
Standard Error	0.012	0.011	0.004	---	---

[1] Minimum lengths (FL) for RSD categories are (Gablehouse 1984):
- Stock - 150 mm
- Quality - 270 mm
- Preferred - 340 mm
- Memorable - 450 mm
- Trophy - 560 mm

[2] RSD calculated directly from the number sampled.

[3] Standard error of sampled RSD.

[4] Tributaries: Two-Bit and Caribou Bay Creeks.

was 6,578 fish (SE = 1,150 grayling; Clark and Ridder 1987b). It is feasible that strong recruitment into the population occurred between June of 1986 and June of the following year, although examination of age class abundance in these 2 years invalidates this hypothesis. It is not biologically possible for there to have been 396 age 5 grayling in Fielding Lake in June of 1986 and then have 3,177 age 6 grayling in the lake the next year (Table 28). There are three plausible causes of the discrepancy between years: 1) the Fielding Lake grayling population is not geographically closed; 2) the 1987 abundance estimate is biased high; and, 3) the 1986 abundance estimate is biased low. The possibility that the aging of grayling scales by the same personnel has changed from 1986 to 1987 samples is remote because the shifts in age class abundance are so large that the error in aging among years would have to be more than just 1 or 2 years.

Case one is plausible, but highly improbable when emigration is considered. Fielding Lake outlet drains into the glacial waters of Phelan Creek and the Delta River. Grayling are not known to utilize glacial rivers for residence in the summer (Tack 1980) and would therefore not emigrate out of Fielding Lake between June and August. The case for immigration is a more likely cause. For example, if after grayling were tagged in June, additional unmarked grayling immigrated from the outlet stream into the lake, the abundance estimate would be biased. Grayling are known to utilize glacial rivers to migrate from one clear water source to another (Tack 1980; Ridder 1985). If these unmarked grayling were larger than the size range detected in recruitment tests, they would not be culled and add to the population of unmarked grayling in the lake during the August sample. Recruitment was detected in the 260 to 317 mm FL size range (Table 27), but the significance of this finding does not prove that immigration had occurred. If immigration of large size grayling had occurred, the population estimate for June 1987 would be biased high.

Case two is also highly likely because if marked grayling did not mix with unmarked grayling between June and August, the estimate of abundance would be biased. The statistical test used to test for mixing is the same as that for length selectivity. This test was not significant, but a closer look at the recapture rate by area of the lake revealed differences that tend to support the lack of complete mixing. Grayling captured in the lake with electrofishing gear in June had a capture probability that was twice as high as grayling captured in the inlet streams with fyke weirs. The reason why grayling tagged while exiting the inlet streams were not recaptured at the same rate as those tagged in the lake is unknown at this time.

Case three is also highly likely because the lack of mixing may have occurred in 1986. Grayling were not captured while exiting inlet streams although many grayling were captured by electrofishing near the mouths of inlet streams (Clark and Ridder 1987b). A similar pattern of recruitment in the 251 to 261 mm FL size range occurred in the 1986 data, although the abundance estimate was stratified by four size classes to adjust for bias due to differential capture probabilities (Clark and Ridder 1987b).

The most plausible explanation may be found in a combination of the first two cases. Immigration may have been occurring after the phase one sample in

June. The additional unmarked grayling may not have caused significant changes in capture probabilities because of incomplete mixing. Sampling of the Fielding Lake system will continue in an attempt to elucidate the true geographic range, abundance, and stock structure of Fielding Lake grayling.

Tangle Lakes System

The Tangle Lakes system was initially surveyed on 21 May to determine the presence of spawning grayling or spawning behavior. The Tangle River between Upper and Round Tangle lakes was free of ice, as was a small portion of Round Tangle Lake adjacent to the Tangle River. Temperature of the Tangle River was 1°C and no fish were observed during visual surveys of the upper or lower reaches. No fish were caught in 2 hours of hook and line sampling at the mouth of the Tangle River main channel. Tack (1980) stated that a water temperature of 1°C initiates migration of grayling to spawning areas. Rock Creek was partially free of ice from the Denali Highway crossing downstream to Upper Tangle Lake, but ice covered from Glacier Lake upstream. Water temperature was 1.5°C at the Denali Highway crossing of Rock Creek.

A small creek (referred to as 18 Mile Creek in this report) that crosses the Denali Highway at milepost 18 and drains into the thoroughfare below Round Tangle Lake was partially clear of ice. Four grayling were observed in 18 Mile Creek from the highway culvert to a point 1 km downstream. This heavily glaciated creek drains into a shallow lake 1 km downstream from the highway crossing. Meltwater from 18 Mile Creek had carved an ice free channel through the center of the frozen lake. In this ice free channel, grayling were seen surface feeding and 23 grayling were captured in 2 hours of hook and line sampling in the area. All fish were greater then 250 mm FL. Some of the male grayling exhibited signs of spawning activity (milt production).

The second and third sampling events at Tangle Lakes were performed during 20 to 23 June and 21 to 28 August. Sampling with three gear types in six areas of the system captured a total of 1,328 grayling; 595 of these grayling were marked with internal anchor tags (Table 32).

Age and Size Composition:

As in 1986 (Clark and Ridder 1987b), grayling age 3 and younger predominated in the June and August Tangle River samples (Table 33). Older grayling comprised a similar proportion in each sample. Examination of mean length at age statistics indicated that growth during the two month hiatus ranged from 50 mm for age 1 grayling to 18 mm for age 5 grayling (Table 34). Recovery of marked grayling in future sampling events should provide more precise estimates of growth.

Ninety-two percent of the June seine sample from the thoroughfare below Shallow Tangle Lake was comprised of age 3 and age 4 grayling (Table 35). The sample came entirely from the head of the thoroughfare even though seining was performed along its entire length. Age 1 and age 2 grayling were absent from the thoroughfare sample. Forty-seven percent of the June sample from the Tangle River was comprised of age 1 and age 2 grayling.

Table 32. A summary of grayling sampling trips performed during 20 to 23 June and 21 to 28 August 1987 in the Tangle Lakes system.

			Number		
Month	Location[1]	Gear	Caught	Tagged	Recaptured[2]
June	Tangle River	seine	439	159	7
June	STLK-TH	seine	86	75	0
June	RTLK-TH	seine	1	1	0
June	RTLK-TR	seine[3]	22	22	0
June	UTLK	electro	24	17	0
June	18 Mile Creek	seine	2	2	0
August	Tangle River	seine	743	311	12
August	RTLK	electro	11	8	0
Totals			1,328	595	19

[1] STLK-TH = Thoroughfare (outlet) of Shallow Tangle Lake
RTLK-TH = Thoroughfare (outlet) of Round Tangle Lake
RTLK-TR = Round Tangle Lake adjacent to mouth of Tangle River
UTLK = Upper Tangle Lake
RTLK = Round Tangle Lake

[2] Grayling recaptured in June were initially marked in September 1986; grayling recaptured in August were initially marked in September 1986 or June 1987.

[3] Purse seine. Other samples were made with beach seines.

Table 33. Estimates of the proportional contribution of each age class and standard error for Arctic grayling captured by seining the Tangle River between Upper and Round Tangle Lakes, 21 to 22 June and 21 to 27 August 1987.

	21 to 22 June:			21 to 27 August:		
Age	n[1]	p[2]	SE[3]	n	p	SE
0	0	---	---	84	0.113	0.012
1	94	0.216	0.020	306	0.412	0.018
2	111	0.255	0.021	111	0.149	0.013
3	136	0.313	0.022	123	0.166	0.014
4	68	0.156	0.017	103	0.139	0.013
5	23	0.053	0.011	13	0.017	0.005
6	3	0.007	0.004	3	0.004	0.002
Total	435	1.000		743	1.000	

[1] n = sample size.

[2] p = proportion of sampled grayling.

[3] SE = standard error of the sampled proportion.

Table 34. Estimates of the mean fork length (mm) at age and standard error for Arctic grayling captured by seining the Tangle River between Upper and Round Tangles Lakes, 20 to 22 June and 21 to 27 August 1987.

	20 to 22 June:			21 to 27 August:		
Age	n[1]	Mean	SE[2]	n	Mean	SE
0	0	---	---	84	78	1
1	94	90	1	306	140	1
2	111	152	1	111	197	1
3	136	198	2	123	231	1
4	68	243	2	103	265	1
5	23	275	3	13	293	6
6	3	302	3	3	336	8
Total	435	175	3	743	177	2

1 n = sample size.

2 SE = standard error of the mean fork length.

Table 35. Estimates of the proportional contribution of each age class, sampled mean fork length (mm) at age, and standard errors for Arctic grayling captured by seining the thoroughfare between Shallow and Long Tangle Lakes, 21 June 1987.

	Age Composition:			Fork Length (mm):	
Age	n[1]	p[2]	SE[3]	Mean	SE[4]
3	35	0.407	0.053	204	2
4	44	0.512	0.054	247	4
5	5	0.058	0.025	253	17
6	1	0.012	0.012	307	---
7	0	---	---	---	---
8	1	0.012	0.012	340	---
Total	86	1.000		232	3

[1] n = sample size.

[2] p = proportion of sampled grayling.

[3] SE = standard error of the sampled proportion.

[4] SE = standard error of the mean fork length.

The incremental RSD indices estimated from the above three samples parallel their respective age compositions, with 87% to 96% stock size grayling in these samples (Table 36). Quality sized and larger fish were somewhat more plentiful in the August sample than in the June samples taken from the Tangle River.

Tag Recaptures:

A total of 45 tag recaptures was obtained from three sources: 19 tags were recovered from the above sampling, 10 were recovered from harvest sampling (sample size of 236; Baker 1988), and 16 were reported by anglers. Recapture locations were the same as tagging locations for 36 (80%) of the recoveries. Of the nine grayling recovered away from the tagging location, seven were recovered upstream of the initial tagging location and two were recovered downstream of the initial tagging location.

There was a discrepancy in tag ratio and movement data between ADF&G recoveries and those reported by anglers. Of the 29 tags recovered by ADF&G (17 tagged in 1986 and 12 tagged in 1987), only three (10%) indicated directional movement. All three of these recoveries were made upstream of the initial tagging location (two from 1986 and one from 1987). Of the 16 tags returned by anglers (four tagged in 1986 and 12 tagged in 1987), six (38%) indicated directional movement. Four of the six grayling moved upstream and two of the six moved downstream.

Of the 10 recoveries from on site creel sampling, seven were initially tagged at and recovered from the Tangle River (four from 1986 and three from 1987 tagging). The creel sample from the Tangle River was 147 grayling, resulting in a recovery rate of 2.7% for 1986 tags and 2.0% for 1987 tags.

ACKNOWLEDGEMENTS

The authors wish to thank Tim Baker, Jared Baker, Mark Ross, Tim Viavant, James Chumbley, David Csepp, Jerome Hallberg, Rolland Holmes, and John H. Clark for their assistance in the field. Thanks also go to lab technicians Jenny East-Cole, Betsy McKracken, and Tony Brown for mounting and reading of grayling scales. Superb technical and analytical assistance was given by David Bernard, Rolland Holmes, and John H. Clark. Special thanks go to Rolland Holmes for reviewing early drafts of this report. This project and report were made possible by partial funding provided by the U. S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U. S. C. 777-777K) under project F-10-3, Job Number G-8-1.

Table 36. Summary of Relative Stock Density (RSD) indices for all grayling (≥ 150 mm FL) sampled by seine in Shallow Tangle Lake outlet and Tangle River in June and August, 1987.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
<u>Shallow Tangle Outlet-June</u>					
Number sampled	83	2	1	0	0
Sampled RSD[2]	0.965	0.023	0.012	---	---
Standard Error[3]	0.020	0.016	0.012	---	---
<u>Tangle River-June</u>					
Number sampled	281	22	0	0	0
Sampled RSD	0.927	0.073	---	---	---
Standard Error	0.015	0.015	---	---	---
<u>Tangle River-August</u>					
Number sampled	359	52	1	0	0
Sampled RSD	0.871	0.126	0.002	---	---
Standard Error	0.016	0.016	0.002	---	---

[1] Minimum lengths (FL) for RSD categories are (Gablehouse 1984):
Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm

[2] RSD calculated directly from the number sampled.

[3] Standard error of sampled RSD.

LITERATURE CITED

Baker, T. T. 1988. Creel census of fisheries in interior Alaska. Alaska Department of Fish and Game, Fishery Data Series, Juneau, Alaska. In prep.

Bernard, D. R. 1983. Variance and bias of catch allocations that use the age composition of escapements. Alaska Department of Fish and Game, Informational Leaflet No. 227, Juneau, Alaska. 53 pp.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1:131-160.

_____. 1952. Inverse multiple and sequential sample censuses. Biometrics 8:286-306.

Clark, R. A. and W. P. Ridder. 1987a. Tanana drainage creel census and harvest surveys, 1986. Alaska Department of Fish and Game, Fishery Data Series No. 12, Juneau, Alaska. 91 pp.

_____. 1987b. Abundance and length composition of selected grayling stocks in the Tanana Drainage during 1986. Alaska Department of Fish and Game, Fishery Data Series No. 26, Juneau, Alaska. 55 pp.

Cochran, W. G. 1967. Sampling techniques, third edition. John Wiley and Sons, New York, New York. 413 pp.

Conover, W. J. 1980. Practical nonparametric statistics, second edition. John Wiley and Sons, New York, New York. 493 pp.

Efron, B. 1981. Nonparametric standard errors and confidence intervals. Canadian Journal of Statistics 9:139-172.

_____. 1982. The jackknife, the bootstrap, and other resampling plans. Society for Industrial and Applied Mathematics, Regional Conference Series in Applied Mathematics, Monograph 38, CBMS-NSF, Philadelphia.

Gablehouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Hallberg, J. E. 1977. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1976-1977, Project F-9-9, 18(R-I). 23 pp.

_____. 1978. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1977-1978, Project F-9-10, 19(R-I). 33 pp.

_____. 1979. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1978-1979, Project F-9-11, 20(R-I). 16 pp.

_____. 1980. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1979-1980, Project F-9-12, 21(R-I). 22 pp.

_____. 1981. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1980-1981, Project F-9-13, 22(R-I). 25 pp.

_____. 1982. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1981-1982, Project F-9-14, 23(R-I). 35 pp.

_____. 1988. Stock assessment, exploitation, and biological characteristics of spawning whitefish in the Chatanika River. Alaska Department of Fish and Game, Fishery Data Series, Juneau, Alaska. In prep.

Holmes, R. A. 1981. Angler effort, exploitation, and value on the upper Chena River, Alaska. M.S. Thesis, University of Alaska, Fairbanks. 118 p.

_____. 1983. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1982-1983, Project F-9-15, 24(R-I). 35 pp.

_____. 1984. Population structure and dynamics of Arctic grayling, with emphasis on heavily fished stocks. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1983-1984, Project F-9-16, 25(R-I). 38 pp.

_____. 1985. Population structure and dynamics of Arctic grayling, with emphasis on heavily fished stocks. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26(R-I). 38 pp.

_____. 1987. Profiles and regulatory preferences of Tanana Drainage sport fishermen. Alaska Department of Fish and Game, Fishery Manuscript Series No. 2, Juneau, Alaska. 44 pp.

Holmes, R. A., W. P. Ridder, and R. A. Clark. 1986. Population structure and dynamics of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-1986, Project F-10-1, 27(G-8-1). 68 pp.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. Biometrika 52:225-247.

Laarman, P. W. and J. R. Ryckman. 1982. Relative size selectivity of trap nets for eight species of fish. North American Journal of Fisheries Management 2:33-37.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monograph No. 62. 135 pp.

Peckham, R. D. 1978. A study of a typical spring-fed stream in Interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1977-1978, Project F-9-10, 19(G-III-G).

Peckham, R. D. and W. P. Ridder. 1979. A study of a typical spring-fed stream in Interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1978-1979, Project F-9-11, 20(G-III-G).

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191. 382 pp.

Ridder, W. P. 1980. A study of a typical spring-fed stream in Interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1979-1980, Project F-9-12, 21(G-III-G): 43-93.

_____. 1981. A study of a typical spring-fed stream in Interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1980-1981, Project F-9-13, 22(G-III-G): 1-58.

_____. 1982. A study of a typical spring-fed stream in Interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1981-1982, Project F-9-14, 23(G-III-G): 1-61.

_____. 1983. A study of a typical spring-fed stream in Interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1982-1983, Project F-9-15, 24(G-III-G): 1-54.

_____. 1984. A study of a typical spring-fed stream in Interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1983-1984, Project F-9-16, 25(G-III-G): 1-49.

_____. 1985. The life history and population dynamics of exploited stocks of Arctic grayling associated with the Delta and Richardson Clearwater Rivers. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26(G-III-G): 1-58.

Robson, D. S. and W. A. Flick. 1965. A non-parametric statistical method for culling recruits from a mark-recapture experiment. Biometrics 21:936-947.

Roguski, E. A. and P. C. Winslow. 1969. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1968-1969, Project F-9-1, 10(16-B): 333-351.

Roguski, E. A. and S. L. Tack. 1970. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1969-1970, Project F-9-2, 11(16-B):303-319.

Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52:249-259.

_____. 1970. The effects of trap response on tag-recapture estimates. Biometrika 26:13-22.

_____. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Co., Ltd. London, U.K. 654 pp.

Skaugstad, C. 1988. Evaluation of Arctic grayling enhancement in the Tanana drainage during 1987. Alaska Department of Fish and Game, Fishery Data Series, Juneau, Alaska. In prep.

Skaugstad, C. and W. P. Ridder. 1987. Evaluation of Arctic grayling enhancement in the Tanana Drainage during 1986. Alaska Department of Fish and Game, Fishery Data Series No. 9, Juneau, Alaska. 14 pp.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical methods, seventh edition. The Iowa State University Press, Ames, Iowa, U.S.A. 507 pp.

Tack, S. L. 1971. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1970-1971, Project F-9-3, 12(R-I). 35 pp.

______. 1972. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1971-1972, Project F-9-4, 13(R-I). 36 pp.

______. 1973. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973, Project F-9-5, 14(R-I). 34 pp.

______. 1974. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1973-1974, Project F-9-6, 15(R-I). 52 pp.

______. 1975. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1974-1975, Project F-9-7, 16(R-I). 35 pp.

______. 1976. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1975-1976, Project F-9-8, 17(R-I). 27 pp.

______. 1980. Migrations and distribution of Arctic grayling, *Thymallus arcticus* (Pallas), in interior and arctic Alaska. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21(R-I). 32 pp.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. LA-8787-NERP, UC-11. Los Alamos National Laboratory, Los Alamos, New Mexico. 235 pp.

Wittes, J. T. 1972. On the bias and estimated variance of Chapman's two-sample capture-recapture population estimate. Biometrics 28:592-597.